Monthly Mean Products
Level 3: Diurnal sampling by merging CERES and geostationary data

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CERES Data Products Workshop
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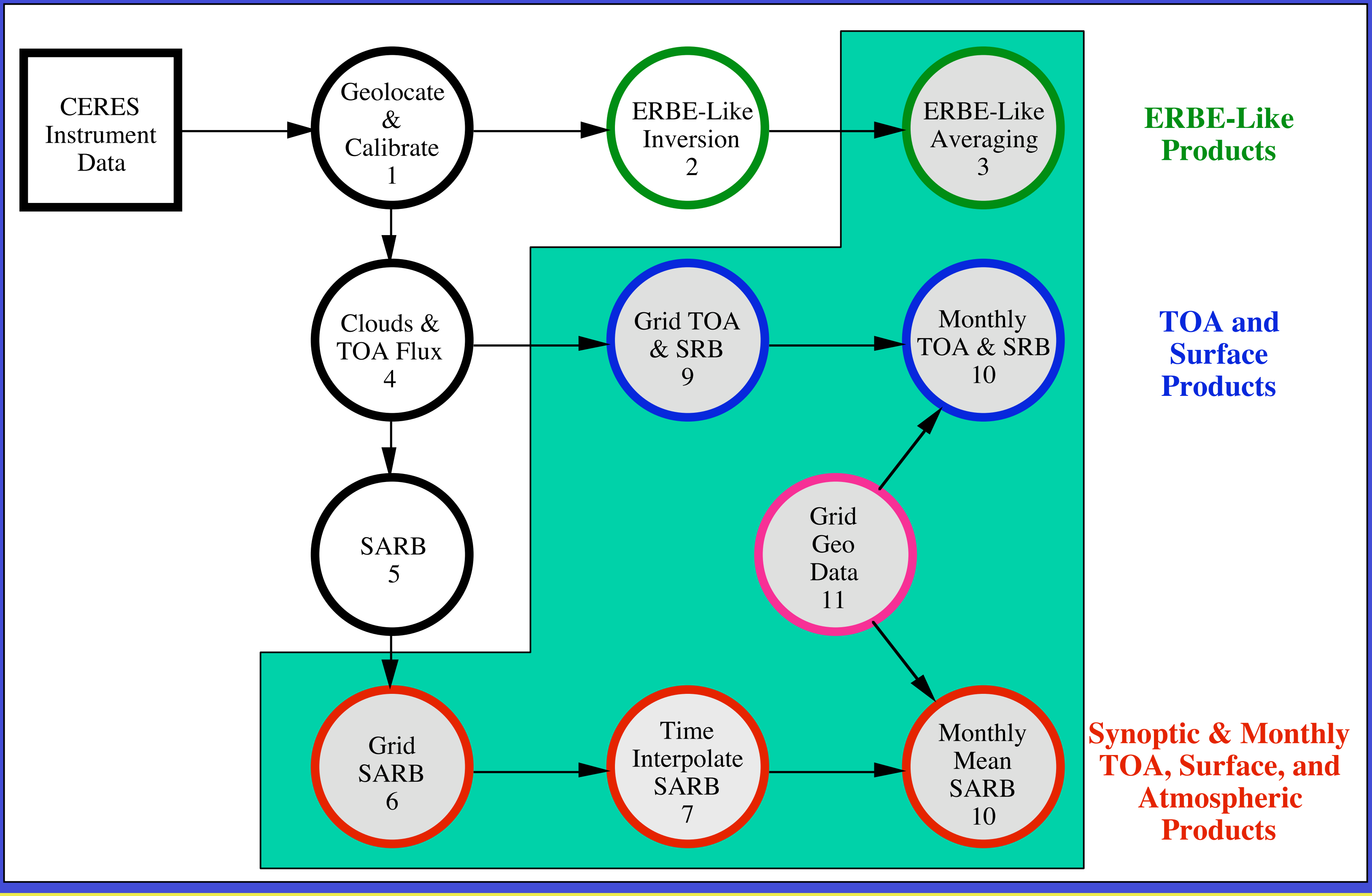
CERES Temporal Interpolation and Spatial Averaging (TISA)

Goals

- Produce climate quality monthly and daily means
  - Must maintain calibration
- Eliminate temporal sampling errors
- Retain consistency among TOA fluxes, cloud properties and surface fluxes
- Produce synoptic maps of TOA, surface, and atmospheric flux

Where TISA Fits Into CERES Processing



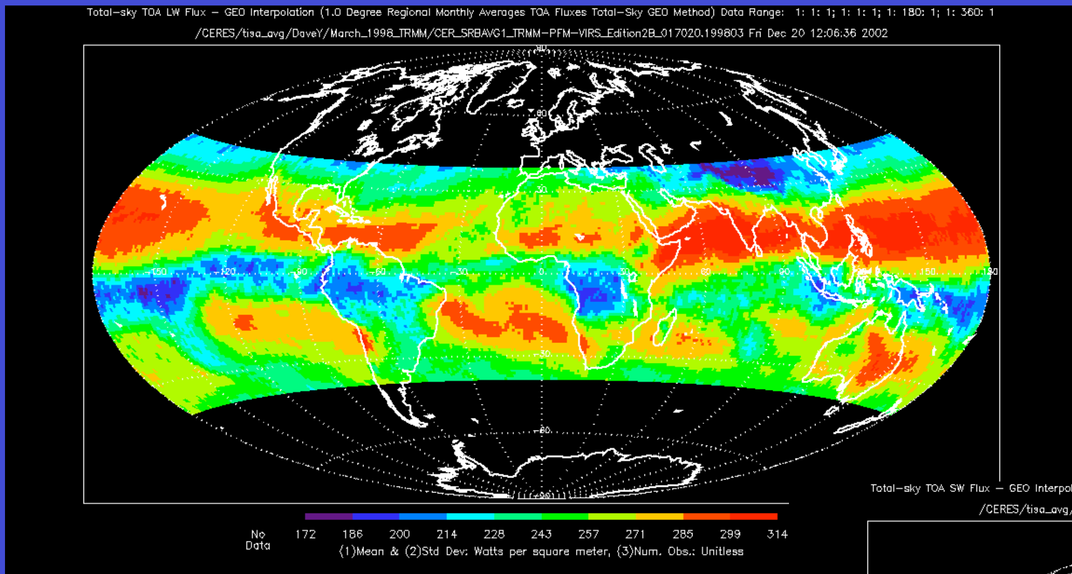
CERES Instantaneous Gridded Data Products

CERES Data Product	Subsystem affiliation	TRMM availability	Terra availability	Aqua availability	ERBElike Product	TOA and Surface Product	Atmosphere Product
ES9 (ERBElike Monthly Regional Averages)	3.0	Edition2	Edition2	Spr '03 Edition1	X		
SFC (Monthly Gridded TOA/Surface Fluxes and Clouds)	9.0	Edition2B	Beta1	2004 Beta1		X	
FSW (Monthly Gridded Radiative Fluxes and Clouds)	6.0	Spr '03 Edition2C	Spr '03 Beta3	2005 Beta1			X
SYN (Synoptic Radiative Fluxes and Clouds)	7.0	2003 Beta1	2004 Beta1	2005 Beta1			X

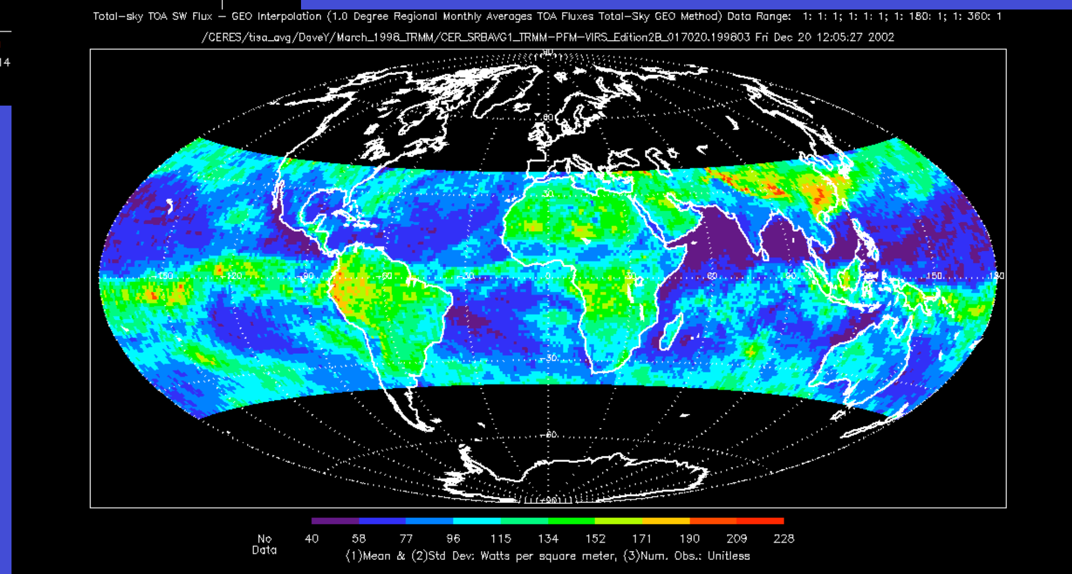
CERES Monthly Gridded Average Data Products

CERES Data Product	Subsystem affiliation	TRMM availability	Terra availability	Aqua availability	ERBElike Product	TOA and Surface Product	Atmosphere Product
ES9 (ERBElike Monthly Regional Averages)	3.0	Edition2	Edition2	Spr '03 Edition1	X		
ES4 (ERBElike Monthly Geographical Averages)	3.0	Edition2	Edition2	Spr '03 Edition1	X		
SRBAVG (Monthly TOA/Surface Averages)	10.0	Edition2B	Spr '03 Beta1	2005 Beta1		X	
AVG (Monthly Regional Radiative Fluxes and Clouds)	8.0	2004 Beta1	2004 Beta1	2005 Beta1			X
ZAVG (Monthly Zonal and Global Radiative Fluxes and Clouds)	8.0	2004 Beta1	2004 Beta1	2005 Beta1			X

Examples from SRBAVG March 1998

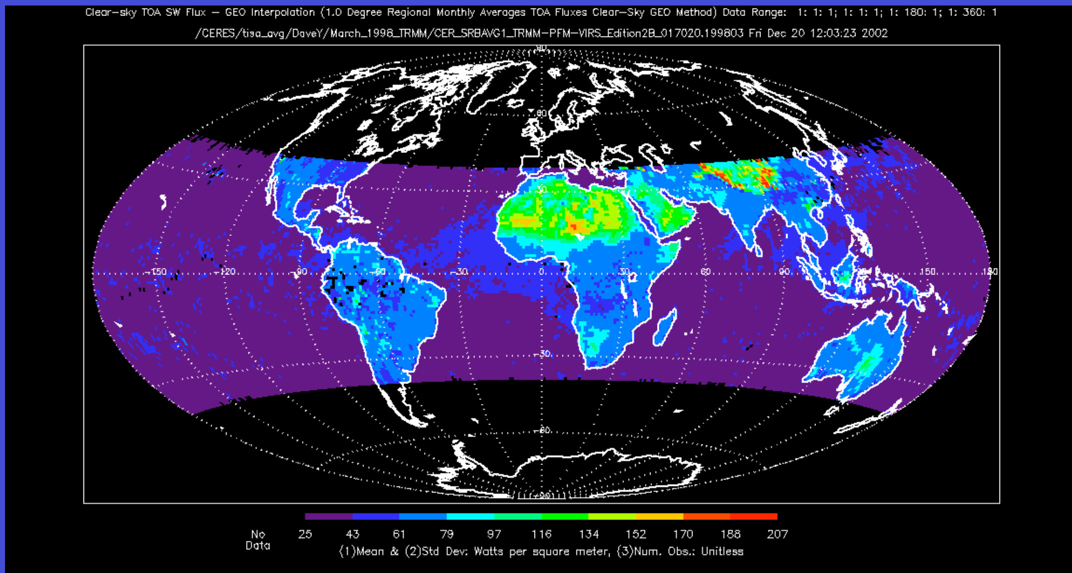


TOA LW Flux

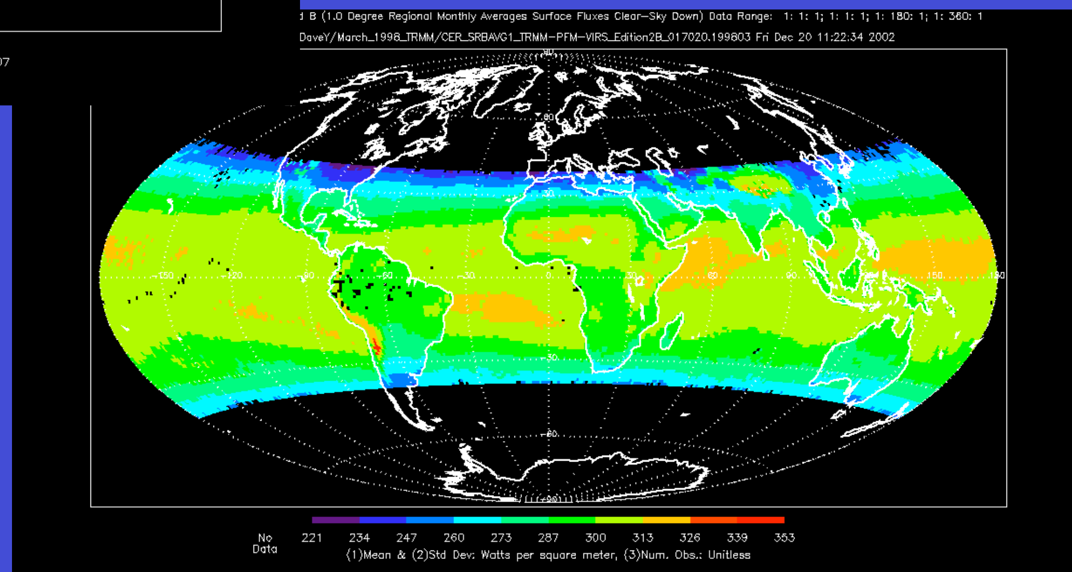


TOA SW Flux

Examples from SRBAVG March 1998



TOA Clear-sky SW Flux



Surface Clear-sky SW Flux

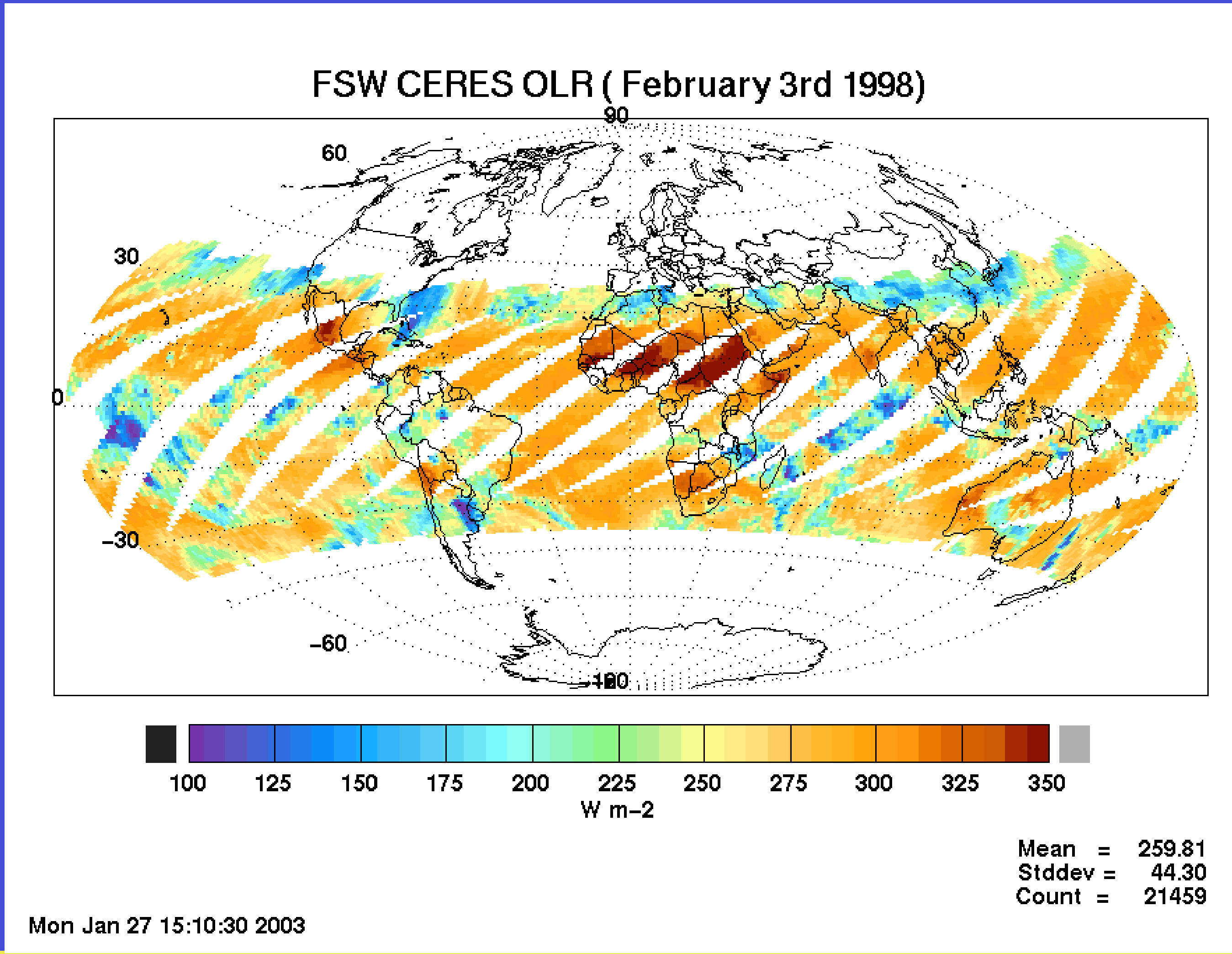
The Steps Needed to Produce Monthly Means

- Step 1: Spatially average
  - Produce instantaneous averages on a fixed grid
  - Products: ES-9, SFC, FSW
- Step 2: Interpolate in time
  - Fill in times between measurements to remove sampling bias
  - Bring in ancillary data to improve accuracy
  - Products: GGEO, SYN
- Step 3: Temporally Average
  - Produce monthly means on a fixed grid
  - Products: ES-4, SRBAVG, AVG, ZAVG

Step 1: Gridding

- Simple averaging of CERES footprints on fixed grid
- SFC
  - Uses SSF as input
  - TOA and surface fluxes
  - Clouds in 4 layers
  - Serves as input to SRBAVG
- FSW
  - Uses CRS as input
  - TOA,surface, and atmospheric fluxes
  - Clouds in 4 layers
  - Serves as input to SYN/AVG/ZAVG

Example of Instantaneous Gridded Data

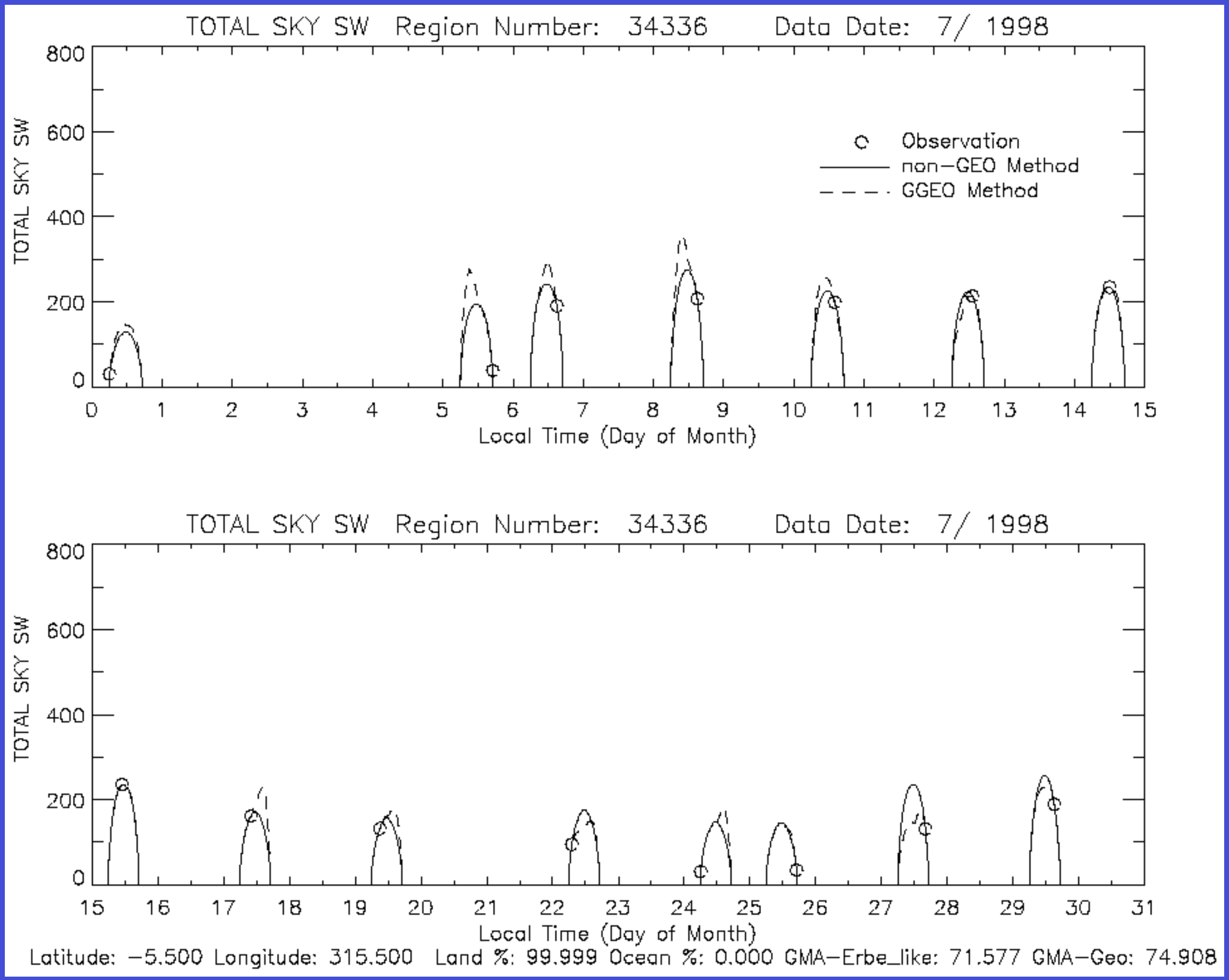


Step 2: Interpolation

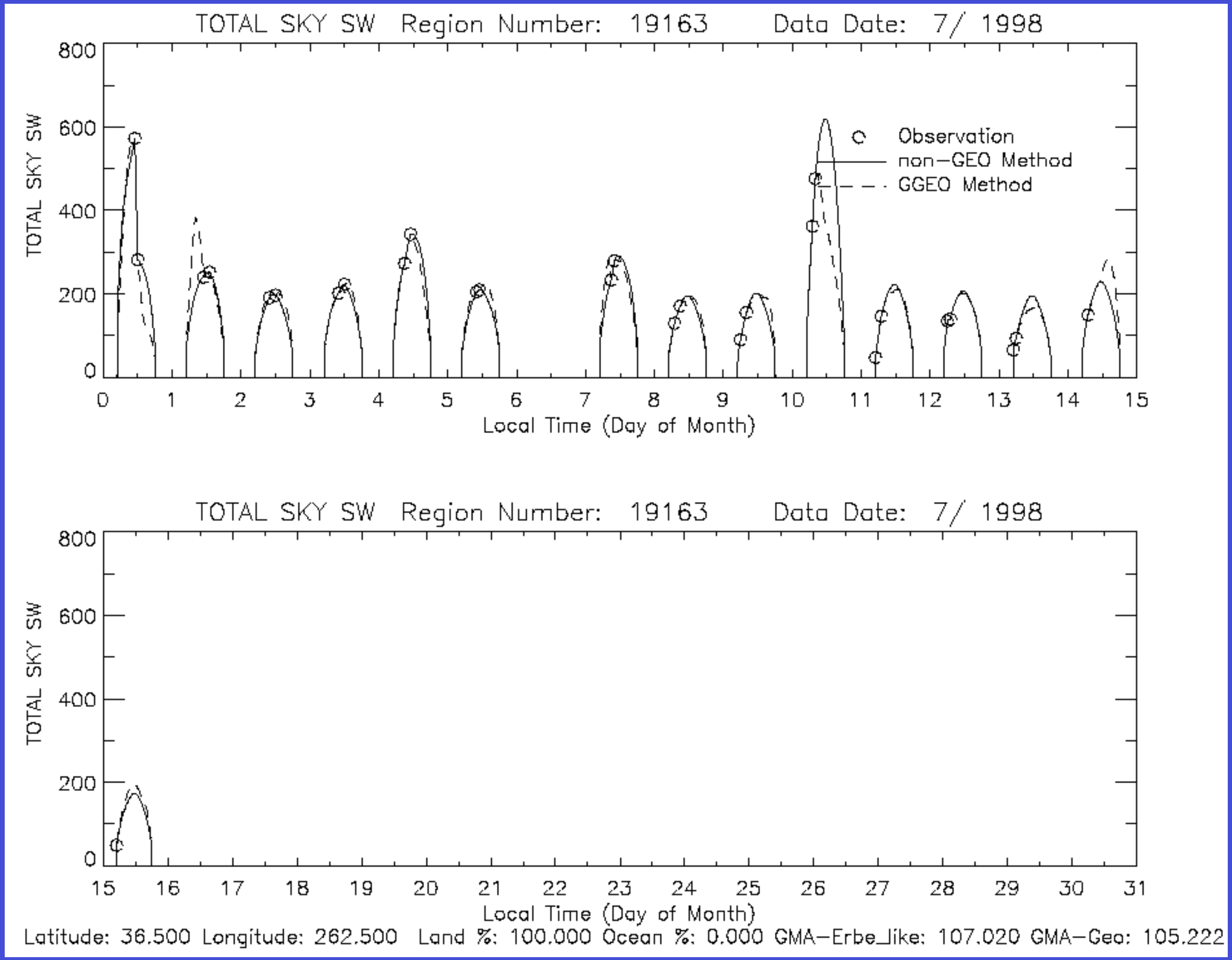
Time Sampling Challenges

- TRMM
  - Latitudinal coverage limited by 35° inclination
  - 46-day precession cycle causes large hemispheric asymmetries
  - VIRS 48° VZA limit
- Terra / Aqua
  - Sun-synchronous orbits limit diurnal sampling

SW Sampling From CERES TRMM
Equatorial Region July 1998



SW Sampling From CERES TRMM
ARM SGP Site July 1998



CERES Interpolation Algorithms

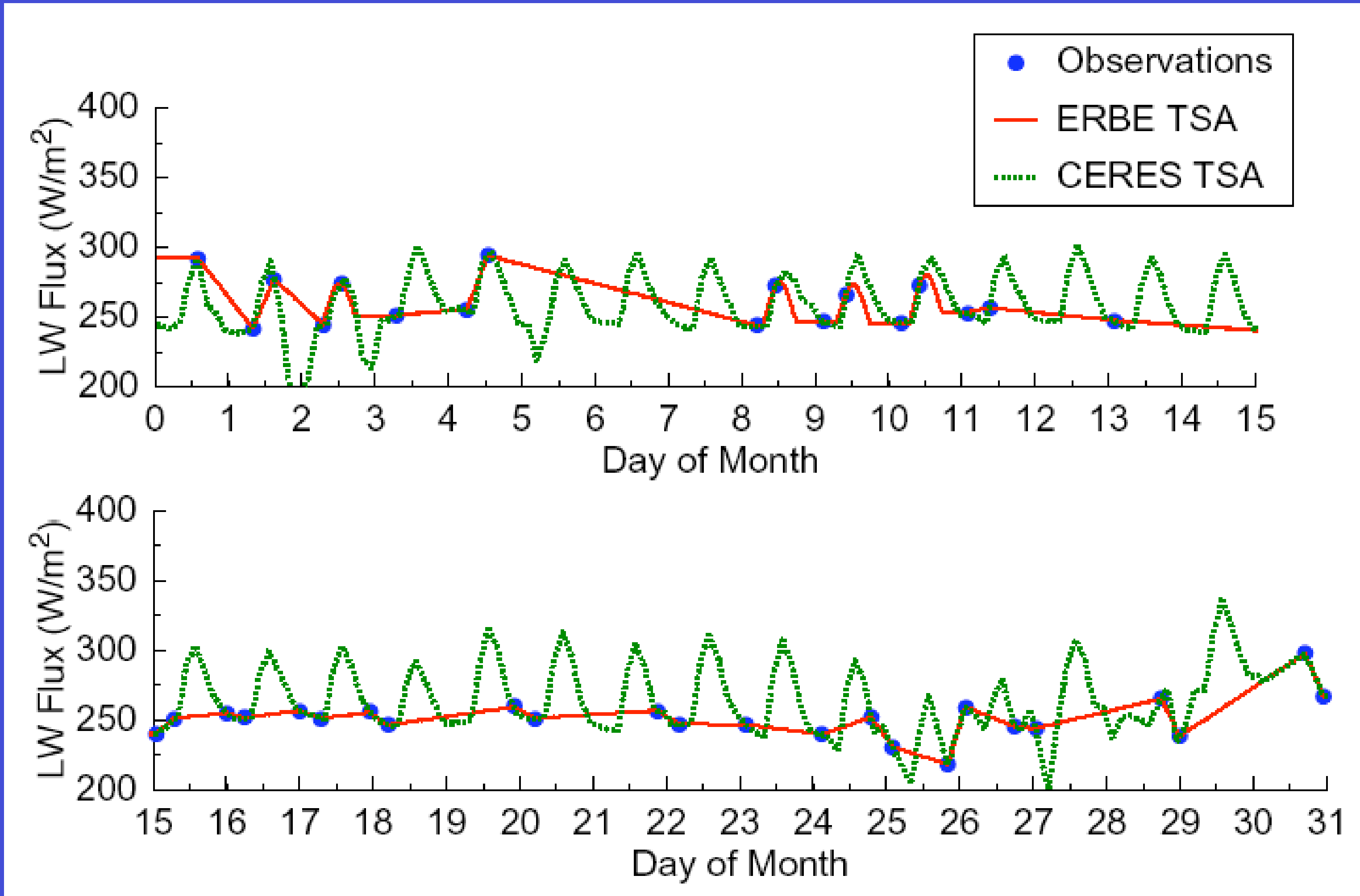
- ERBElike
  - Assumes constant meteorology between observations
  - Uses no ancillary data
  - LW
    - Linear interpolation
    - Simple diurnal modeling over land regions
  - SW
    - Interpolation performed using directional models of albedo
    - Only 12 simple scene types
- CERES nonGEO
  - Same approach as ERBElike
  - Uses new CERES directional models (~200 scene types)

Using Geostationary Data for Temporal Interpolation of TOA Fluxes

- 3-hourly imager data from geostationary satellites is used to define diurnal variations between CERES observations
- Calibration is critical
  - GEO imagers calibration tied to VIRS
- Cloud retrieval is a subset of CERES VIRS algorithm
- Narrowband GEO data converted to flux using NB-BB relationship & CERES ADMs
- Final fluxes are normalized to CERES observations

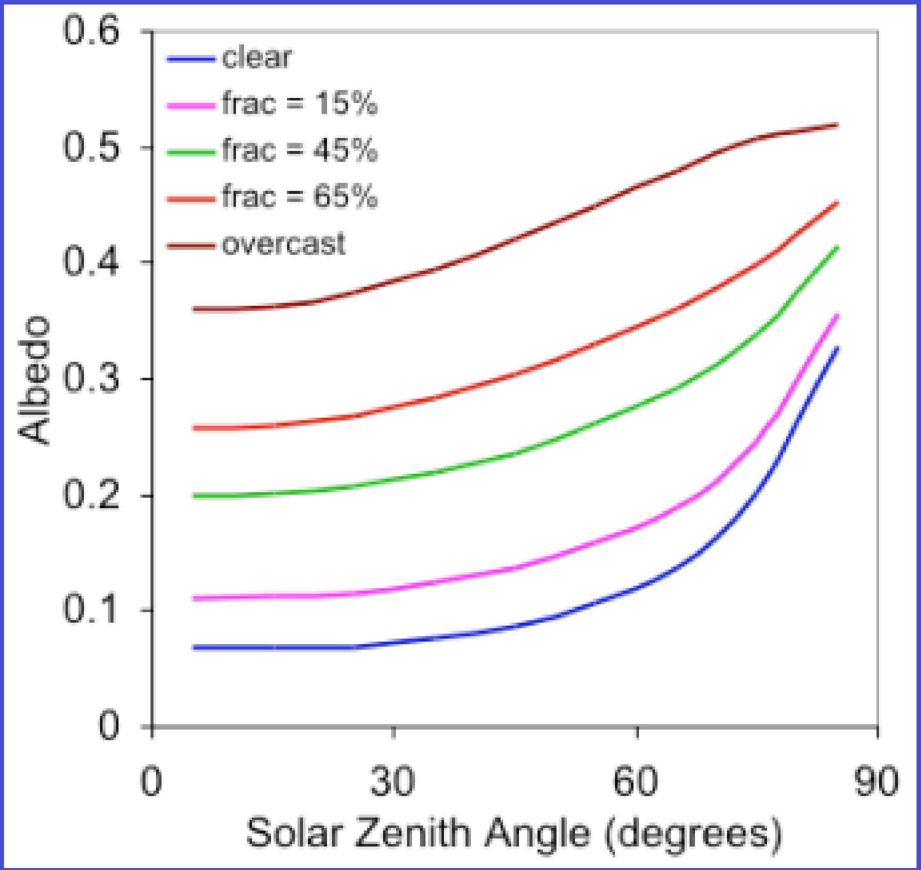
Temporal Interpolation of TOA LW Flux

January 1998 E. Sahara 24.5N 20.5E

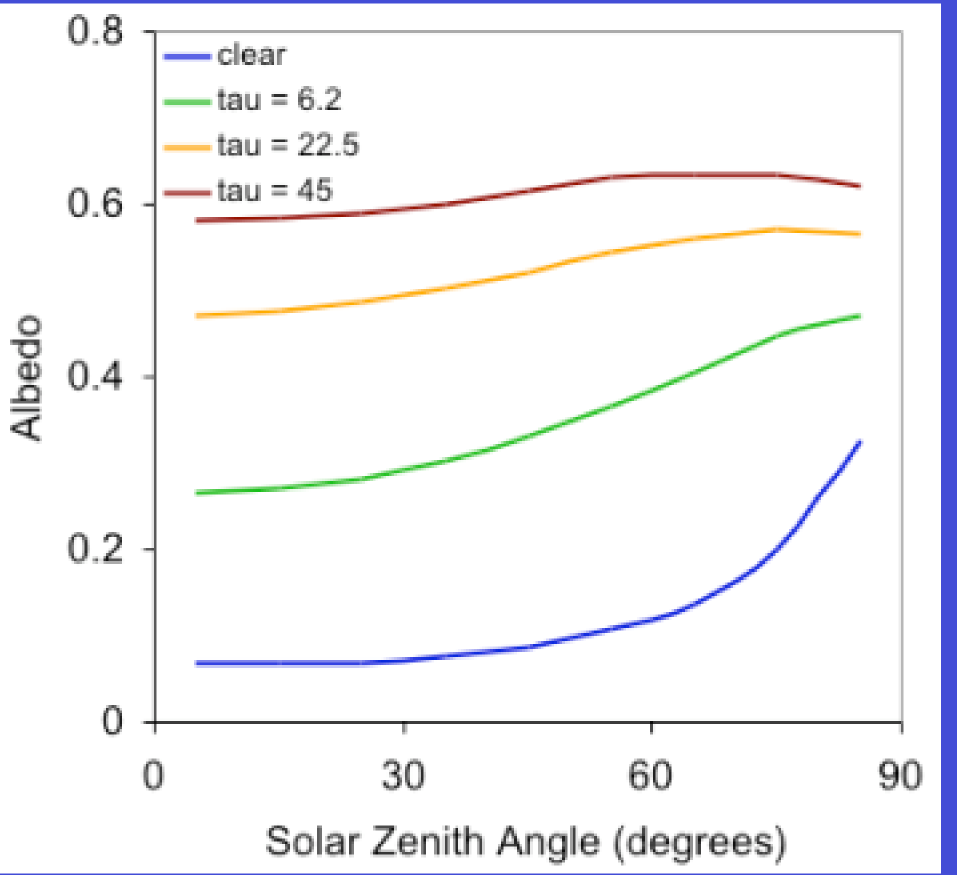


Temporal Interpolation of SW Flux

Optical depth = 11
Variation with Cloud Fraction

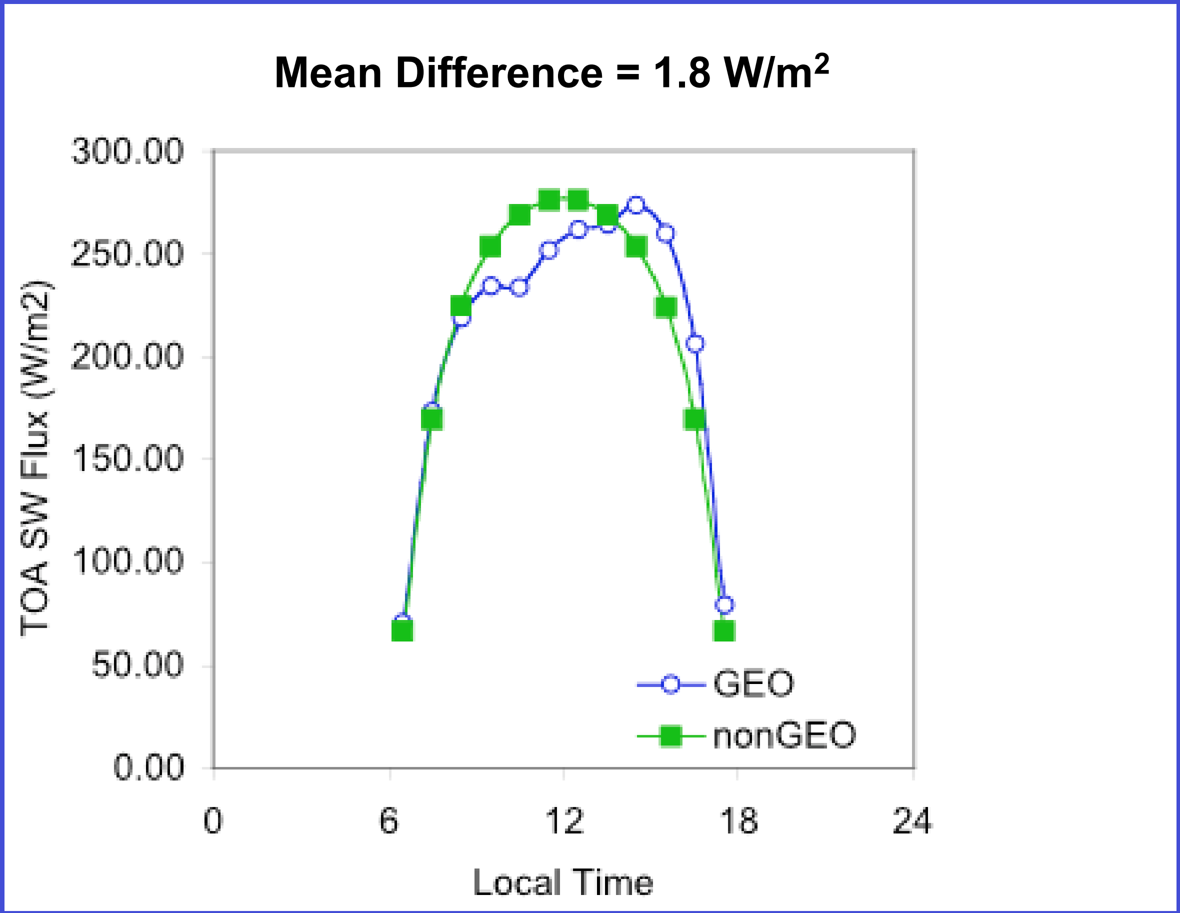


Overcast Models
Variation with Optical Depth

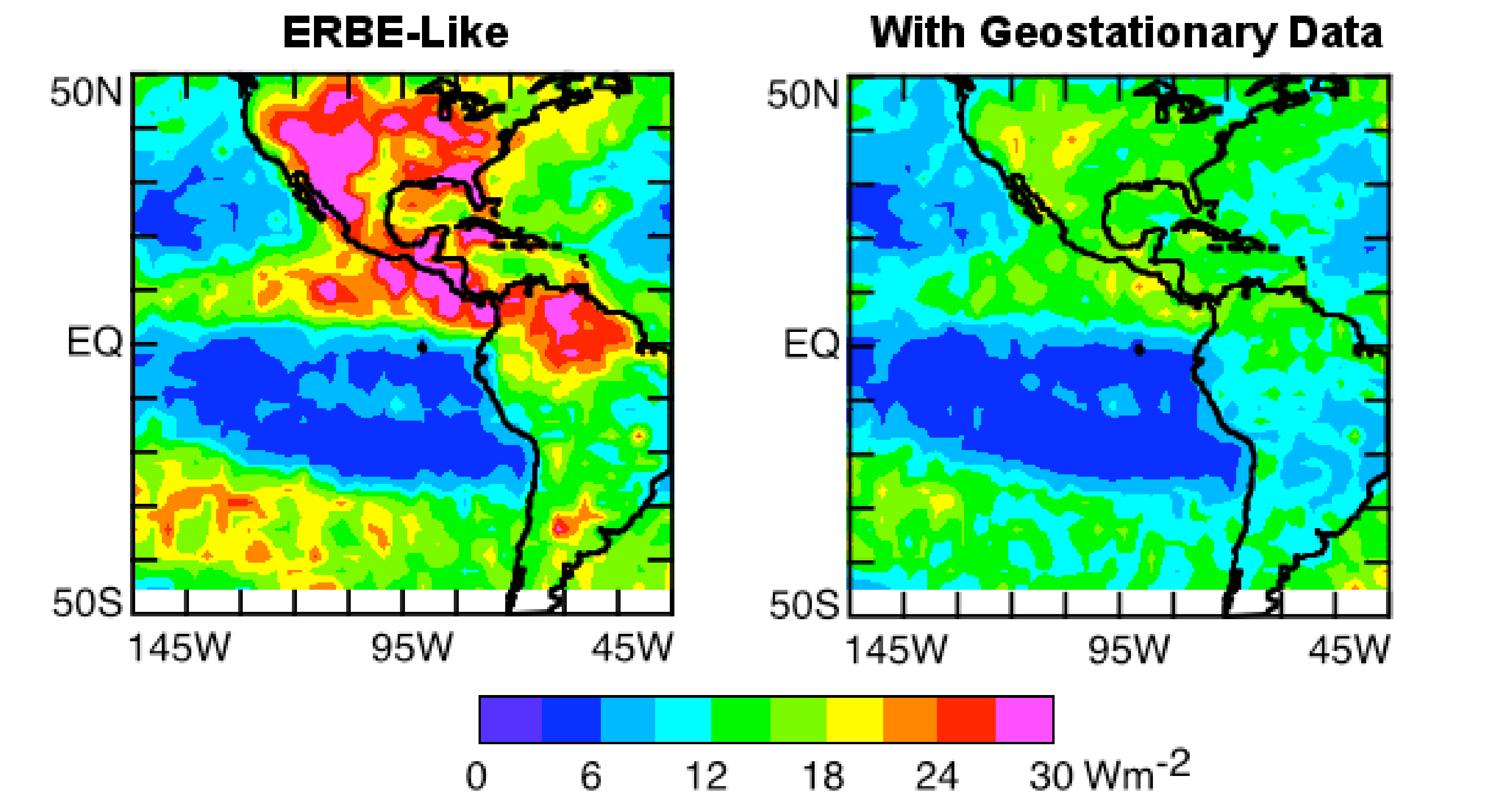


GEO vs. nonGEO Monthly Mean Diurnal SW Flux

Equatorial Pacific Region CERES DRM



Temporal Interpolation RMS LW Flux Errors



Mean Instantaneous Interpolation Rms Errors Are Reduced By 50% For Both LW And SW TOA Flux Using Geostationary Data

Step 3: Averaging

CERES Monthly Mean Products

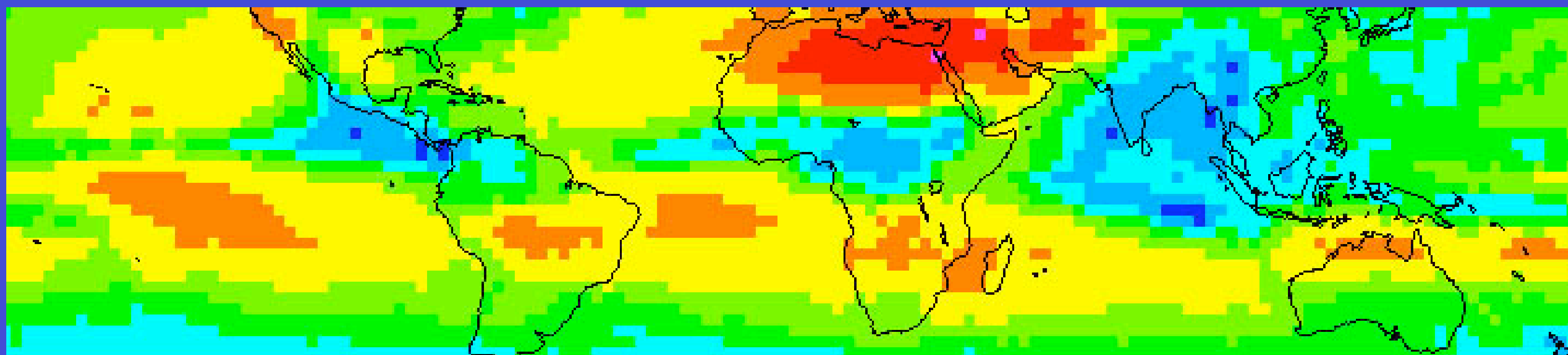
ERBE-like	SRBAVG
• Consistent with ERBE processing • Useful for comparisons with ERBE climatology	• Takes advantage of improved CERES fluxes • Uses improved temporal interpolation to remove sampling effects
• 2.5° grid • TOA fluxes • Limited cloud information	• 1.0° grid • TOA and surface fluxes • Detailed cloud properties
	• Product contains GEO and nonGEO monthly means

ERBE-like / nonGEO Comparisons

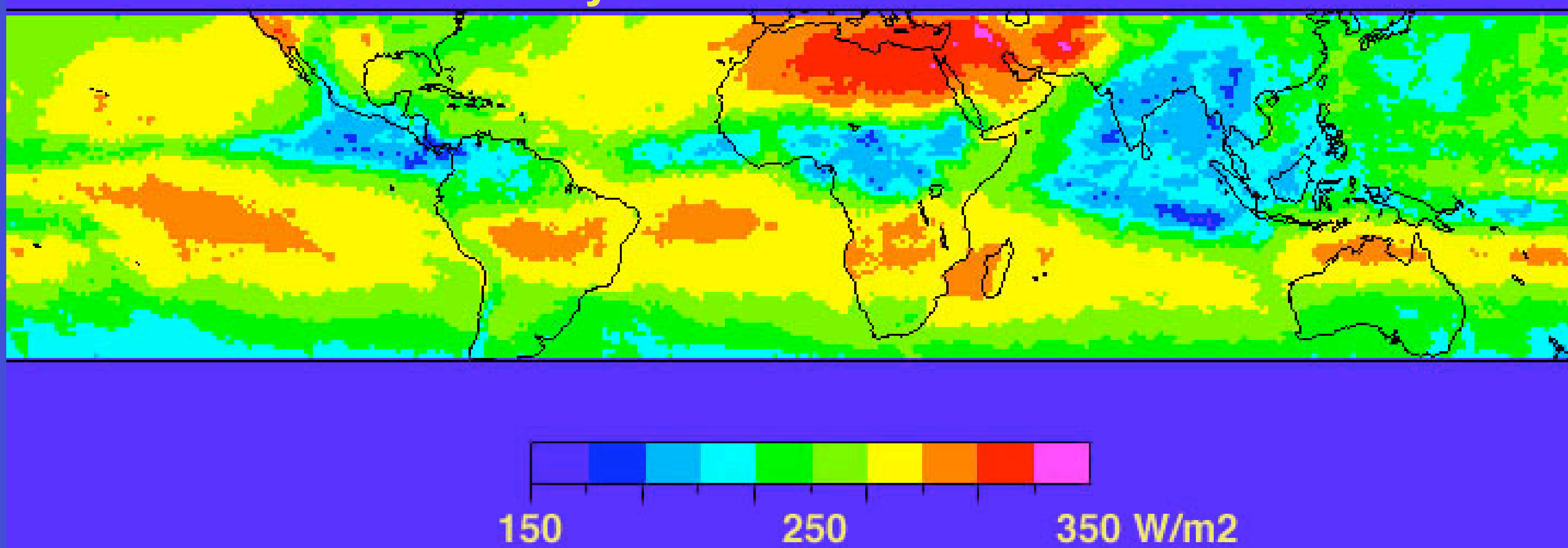
- nonGEO interpolation algorithm similar to ERBElike
- Major differences
  - 1° grid
  - CERES DRMs for SW
  - Input flux differences
    - CERES vs. ERBE ADM
    - Reference altitude: Surface vs. 30-km
    - VZ limit: 48° vs. 70°
- Comparisons use matched monthly means on 2.5° grid
  - SRBAVG nonGEO regridded to 2.5° grid

Monthly Mean CERES TRMM TOA Total-sky LW Flux

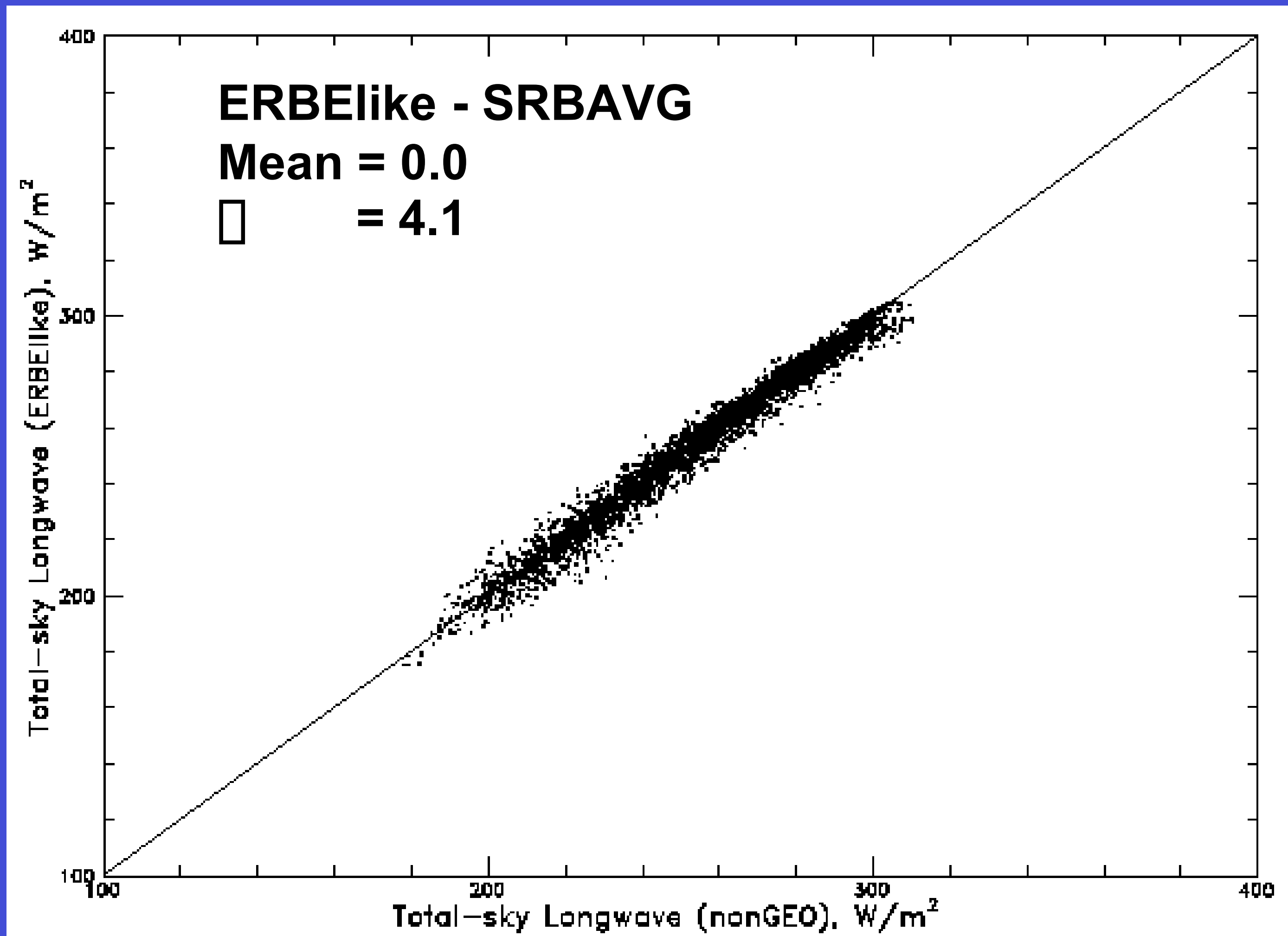
July 1998 ERBE-like



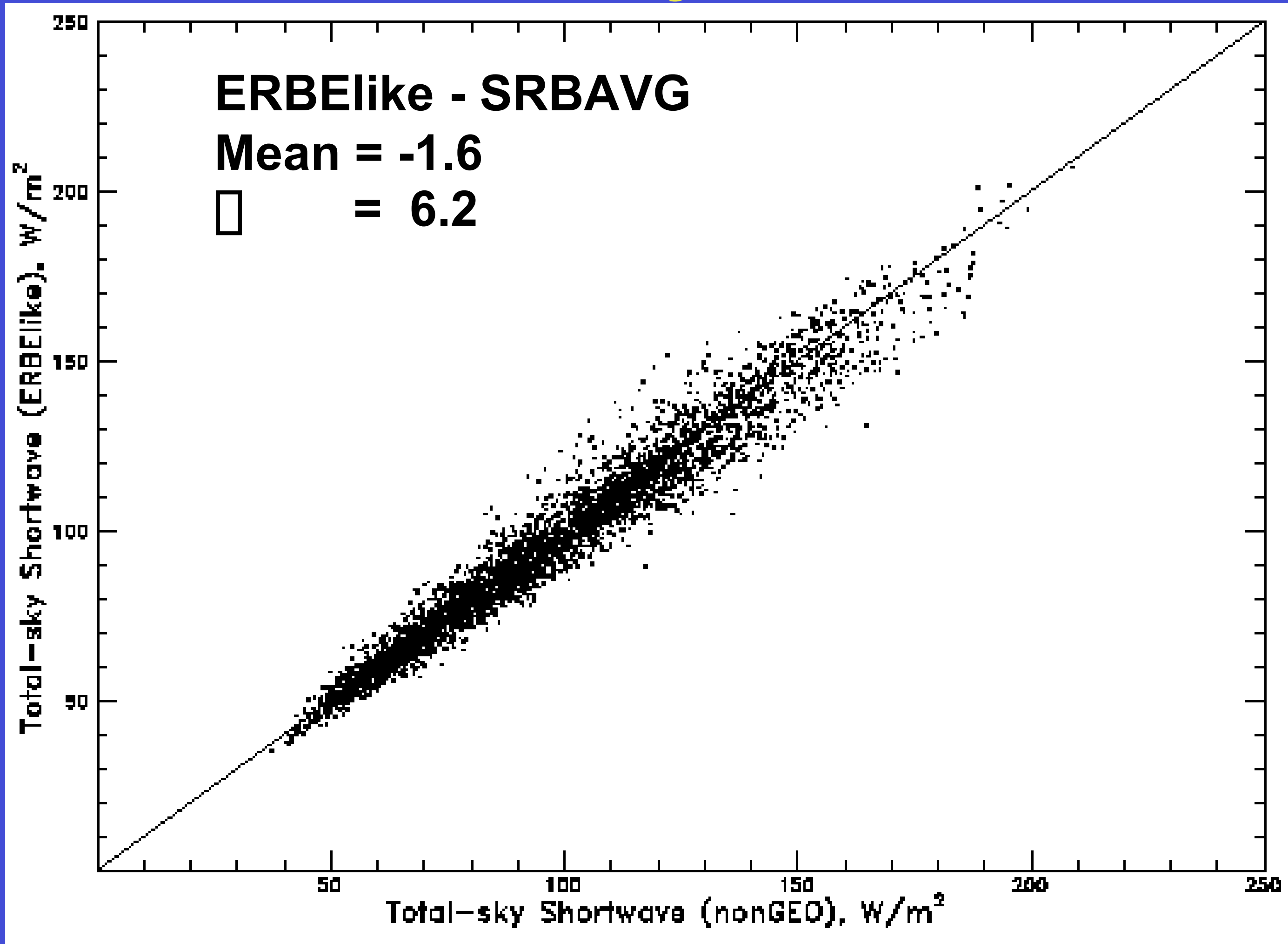
July 1998 SRBAVG nonGEO



ERBElike vs nonGEO Total-Sky LW Flux
February 1998



ERBElike vs nonGEO Total-Sky SW Flux February 1998



ES4 ERBE-like and SRBAVG Flux Summary
February 1998

40°N - 40°S W/m^2		ERBE-like (ES-4)	SRBAVG nonGGEO	ES4 - SRBAVG
Total-Sky LW Flux	Mean	258.3	258.4	0.0
	Sigma	28.5	28.5	4.1
Total-Sky SW Flux	Mean	96.0	97.6	-1.6
	Sigma	29.6	30.4	6.6
Clear-Sky LW Flux	Mean	287.3	287.4	-0.1
	Sigma	12.9	14.0	3.0
Clear-Sky SW Flux	Mean	49.7	49.7	-0.1
	Sigma	18.3	18.3	5.6

SRBAVG nonGEO vs. GEO Fluxes

- Comparison demonstrates changes due to inclusion of GEO data
  - GEO goal is reduction of temporal sampling errors
  - Major improvement expected in mean diurnal variation
- More direct comparison than ERBElike
  - Same input fluxes
  - Same 1° grid
- No GEO SW clear-sky fluxes

GEO Calibration and Cloud Retrievals

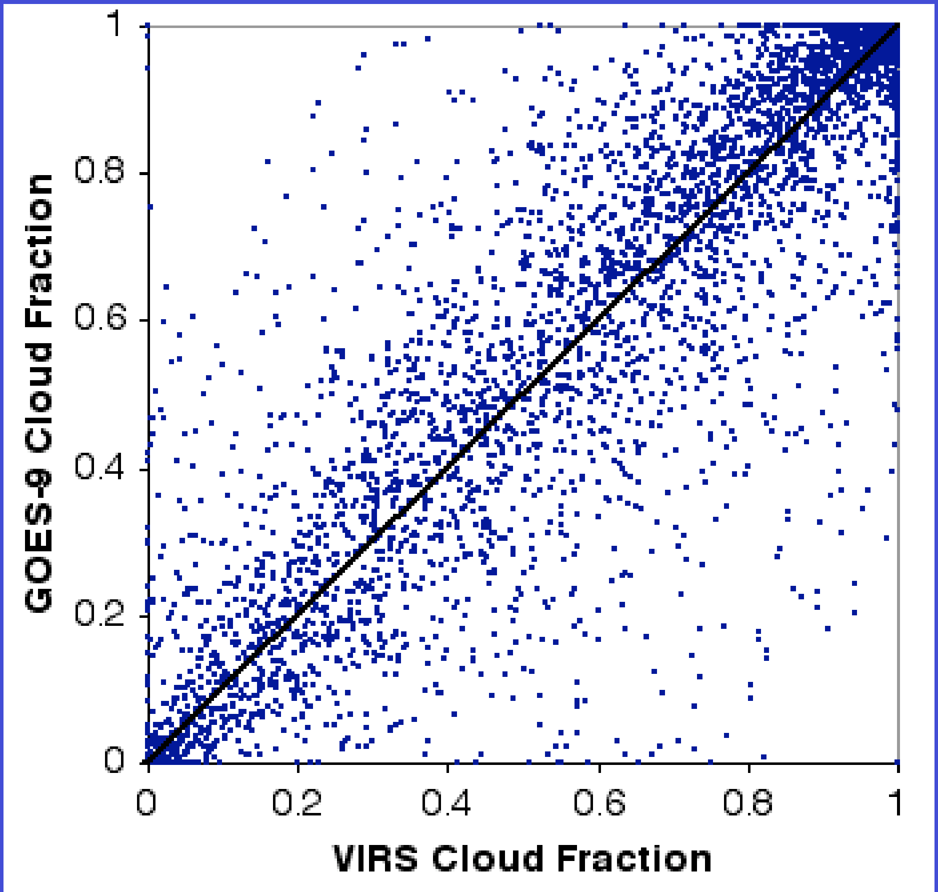
- GEO cloud properties retrieval goals:
  - Improvement of TOA flux interpolation (primary goal)
  - Improvement of diurnal modeling of cloud properties
- GEO calibration goals:
  - Consistency with VIRS calibration
  - Consistency with VIRS cloud retrievals
    - Most important parameter: cloud fraction
    - Optical Depth also used for DRM selection
    - Cloud temperature only used to sort by height
- Limitations
  - Only two channels (0.6 and 10.8 µm)
  - Single channel used at night
  - GEO spectral differences

GEO Calibration (Technique)

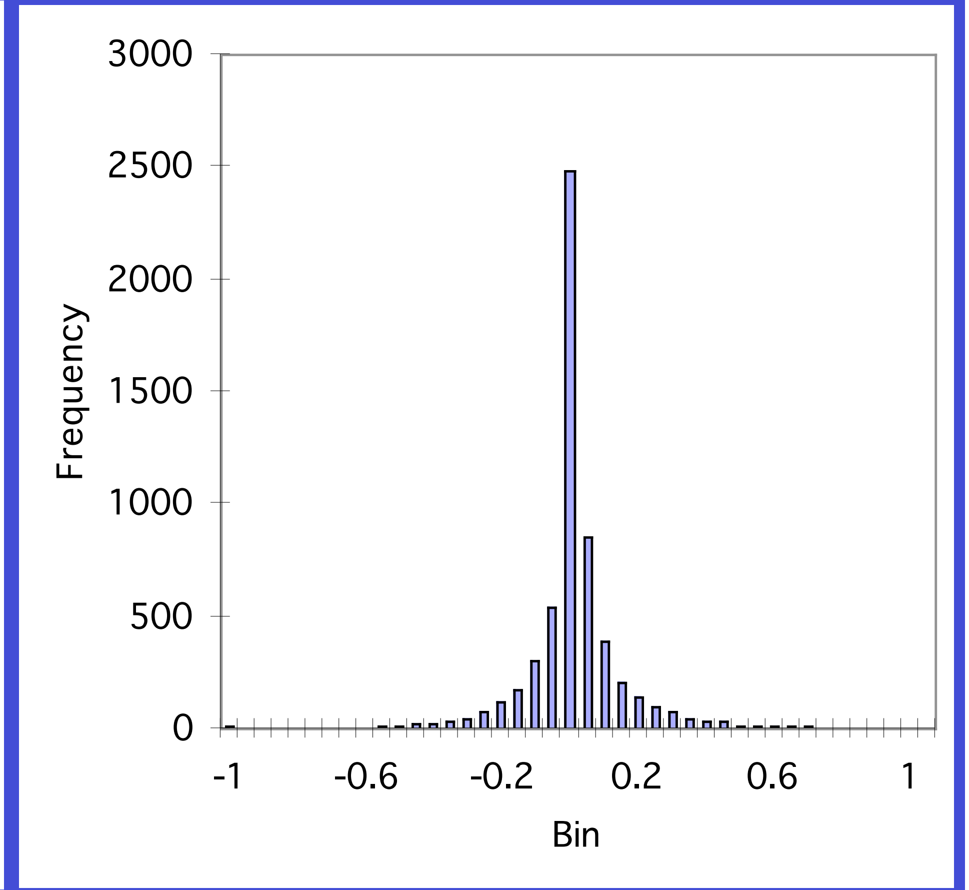
- VIRS/GEO calibration relationship calculated for:
  - Each Month
  - Each GEO satellite
  - Ocean / land / desert
  - 0.65 and 11 μm channels
- VIRS / GEO matched in space/time/viewing geometry
- Visible fit solves for slope and offset
- IR fit uses fixed intercept
- Time series of calibration used to check consistency
  - VIRS vs. nominal calibration compared at high and low radiance values (evaluates combined offset + gain)
  - Some variation expected due to sampling
  - Minnis et al. 2002 uses mean trend line

Instantaneous VIRS-GOES-9 Comparison
Ocean Daytime Cloud Percentage

VIRS: 71.1%   GOES-9: 71.7%



Mean Difference: 0.6%   RMS:14.1%



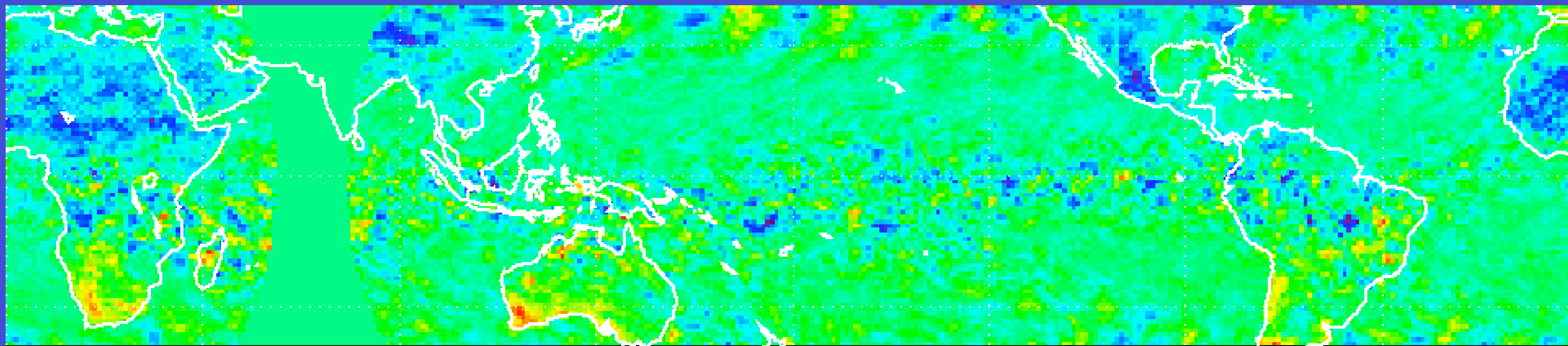
VIRS/GEO Cloud Property Comparison

	Cloud Fraction		Optical Depth		Cloud Temperature (K)	
	VIRS	GEO	VIRS	GEO	VIRS	GEO
Ocean Day	0.60	0.63	6.7	5.4	275.5	271.5
Ocean Night	0.60	0.55			266.5	275.9
Land Day	0.54	0.67	10.1	7.0	268.7	264.5
Land Night	0.51	0.55			251.9	266.9

VIRS-GEO Cloud Fraction by Satellite Demonstrates Inter-satellite Consistency

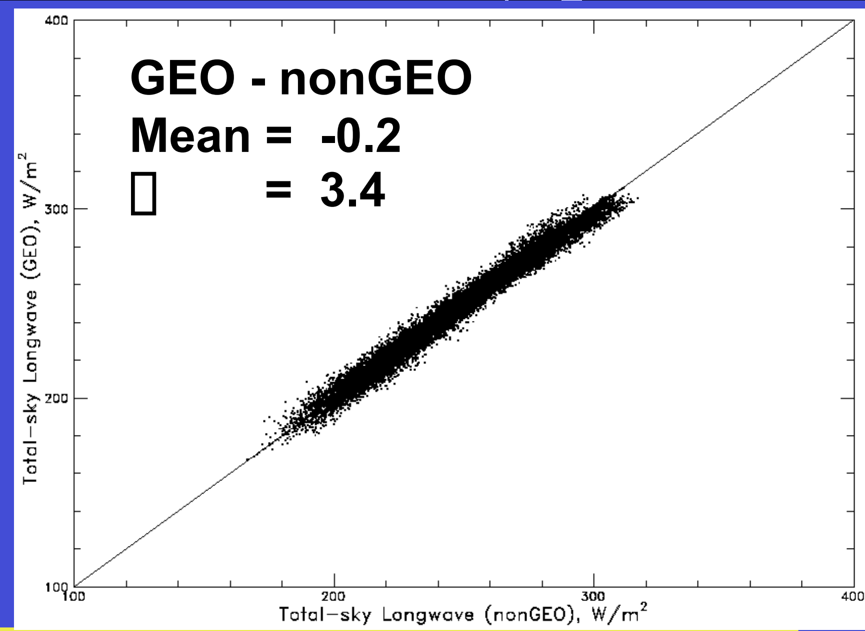
	GOES 8/9/10	METEOSAT 5/6/7	GMS 5
Ocean Day	-0.03	-0.01	-0.01
Ocean Night	0.05	0.06	0.06
Land Day	-0.13	-0.13	-0.14
Land Night	-0.02	-0.04	-0.04

nonGEO vs. GEO Monthly Mean Total-sky LW Flux (February 1998)



-20 0 20

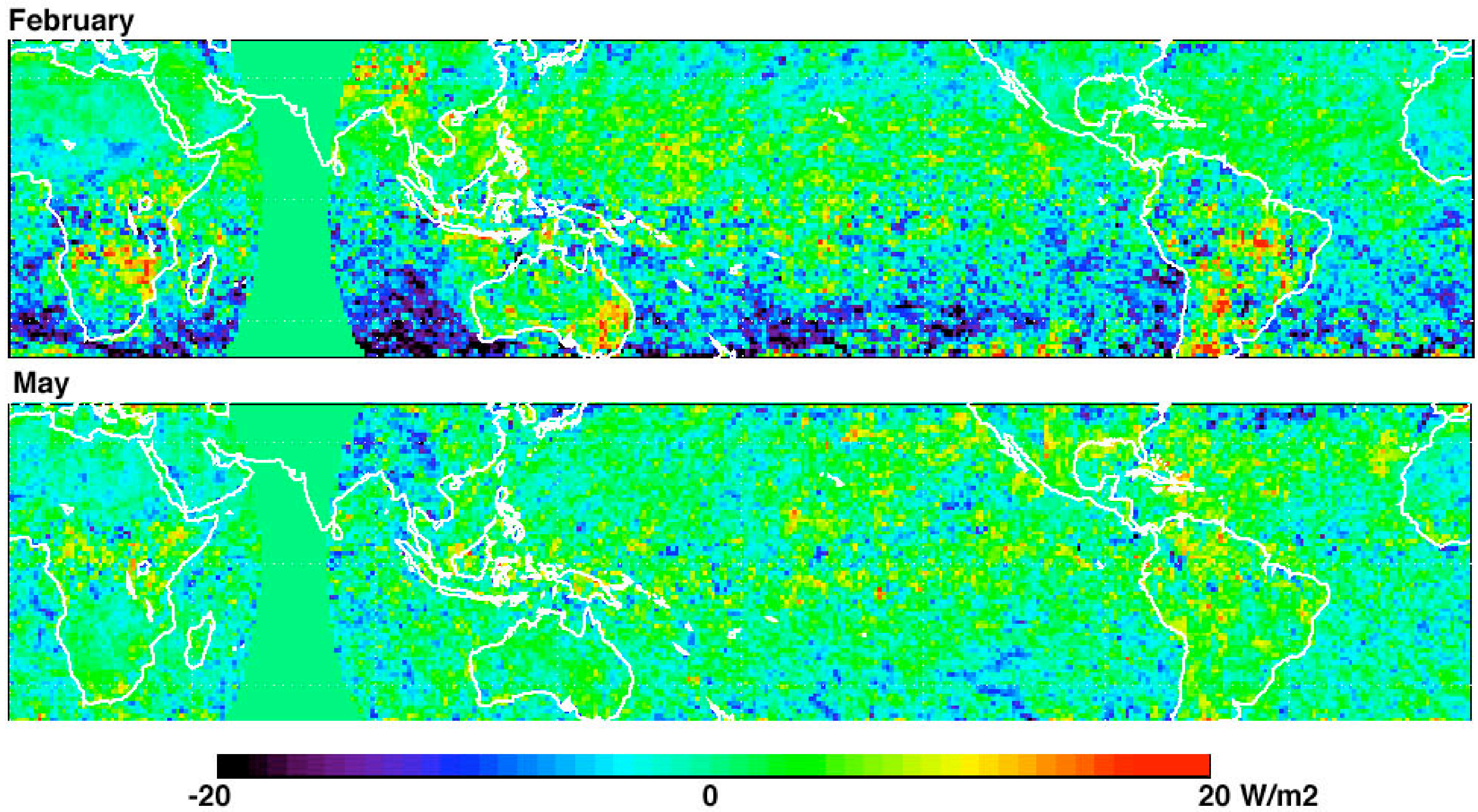
GEO - non GEO Flux (W/m2)



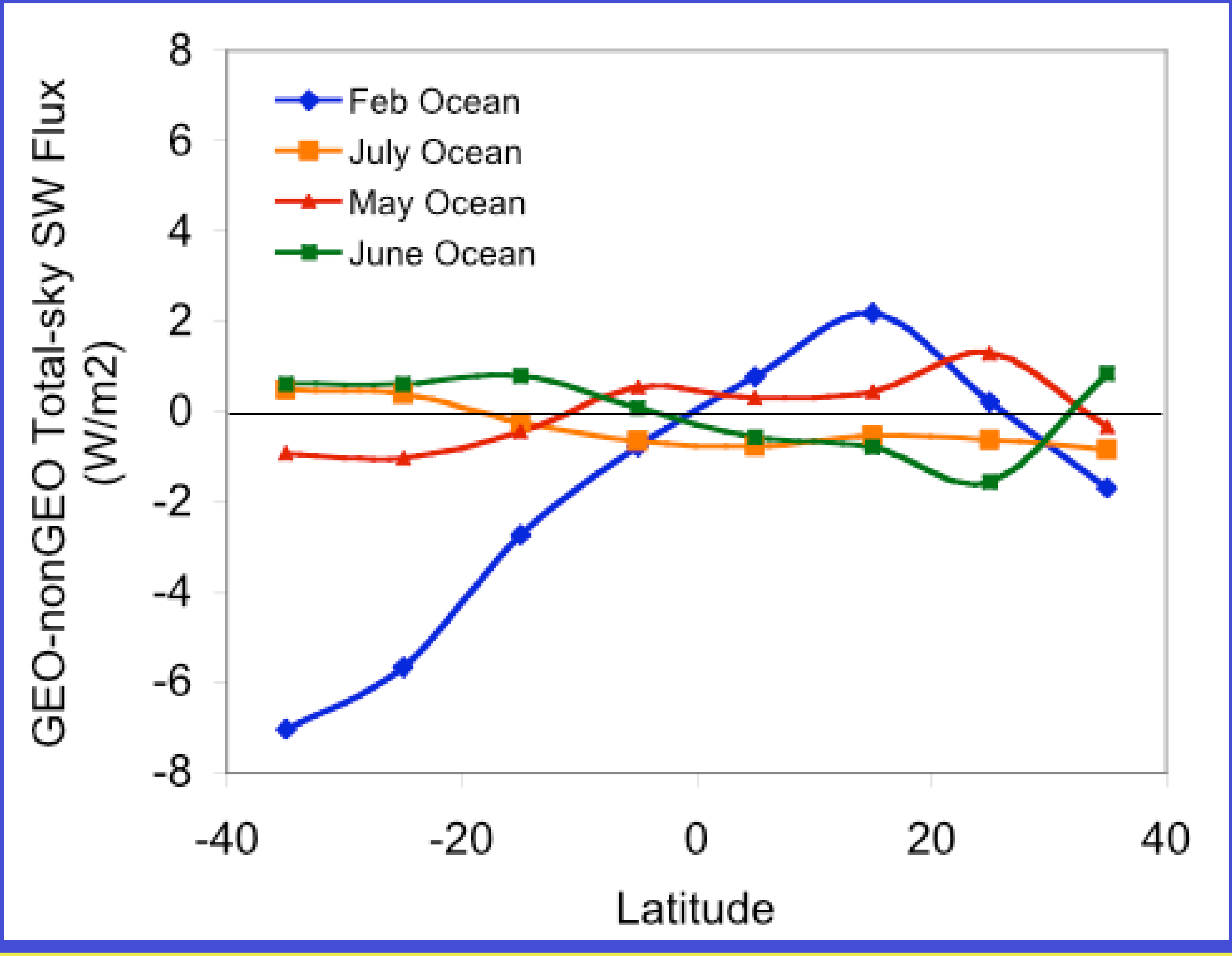
SRBAVG GEO - nonGEO Fluxes
February/May/June/July 1998

40°N - 40°S W/m^2		Feb	May	June	July
Total-Sky LW Flux	Mean	-0.2	0.3	0.2	0.1
	Sigma	3.4	2.9	3.4	3.2
Total-Sky SW Flux	Mean	-1.2	-0.2	-0.7	0.3
	Sigma	6.2	4.4	4.0	4.5
Clear-Sky LW Flux	Mean	-1.1	-1.0	-1.4	-1.0
	Sigma	3.6	1.6	1.7	2.2

Monthly Mean GEO-nonGEO Total-sky SW Flux

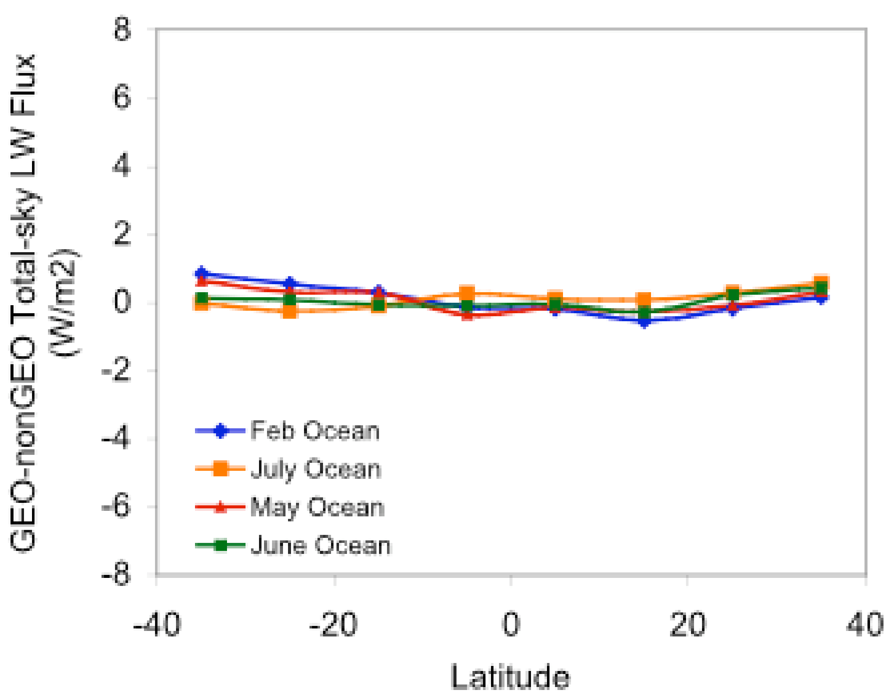


Zonal Mean GEO-nonGEO Total-Sky SW Flux Differences

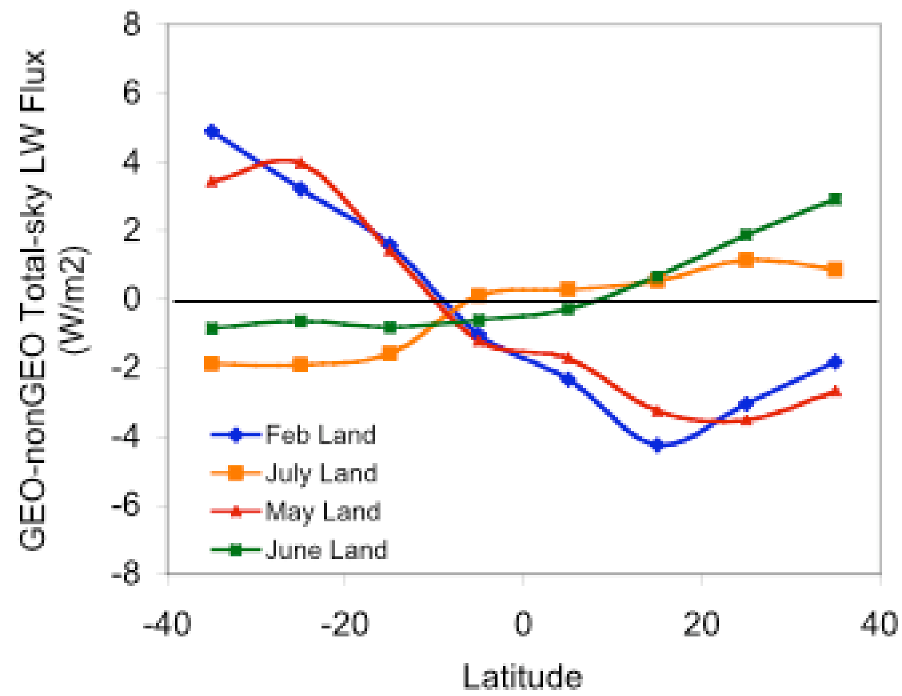


April Zonal Mean GEO-nonGEO LW Flux Differences

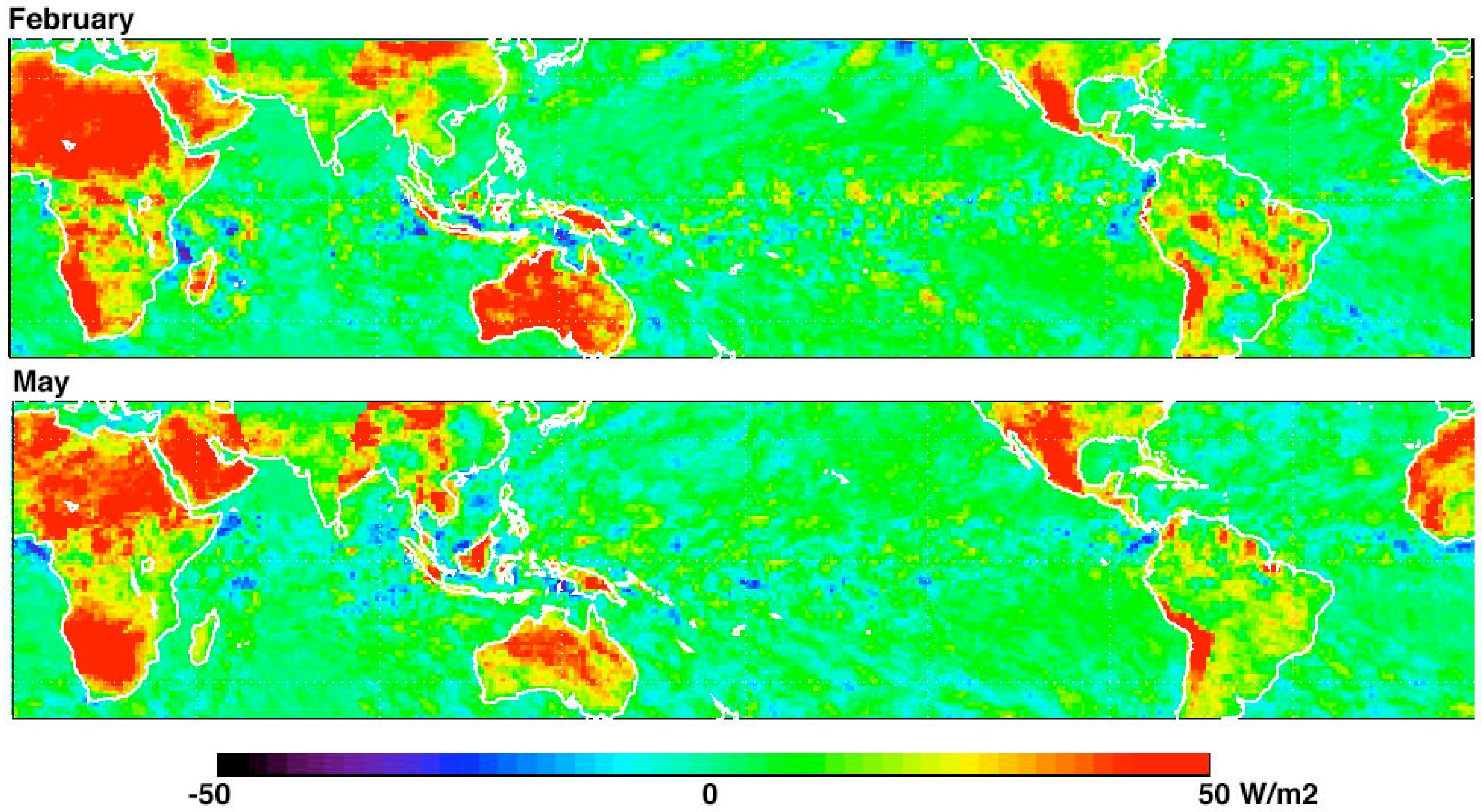
Ocean



Land



Monthly Mean GEO-nonGEO Total-sky LW Flux Diurnal Range



Validation

- GEO calibration
  - Calibration sensitivity test
  - Cloud property comparisons with VIRS and ISCCP
- Direct Integration
  - Compare albedos from interpolation with observations composited from observations over a complete precession cycle
- Surface Flux Comparisons
  - Instantaneous comparisons
  - Monthly means
  - Comparisons with SRB

GEO Calibration Sensitivity Tests

- Goal: Test effect of imager calibration on monthly mean fluxes
- Test by varying imager gain by ±5%
- Calibration affects both radiances and cloud retrievals
  - Cloud properties affect selection of DRMs
  - Cloud mask affects selection of clear-sky radiances

Calibration Sensitivity Summary

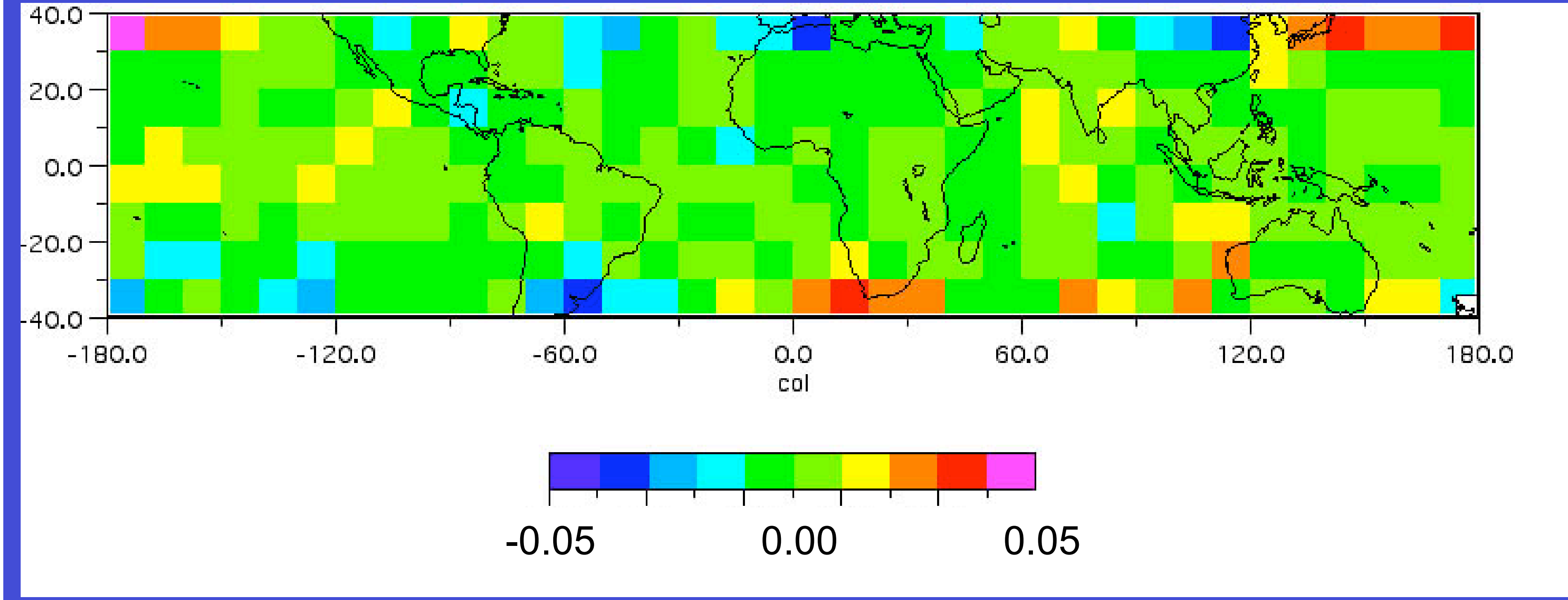
(Change in monthly mean flux due to a ±5% imager calibration error)

	Mean Flux	Mean & rms Flux Difference (W/m^2)			
		IR + 5%	IR - 5%	Vis + 5%	Vis - 5%
Total-sky LW	257.6	0.01 (0.08)	-0.01 (0.08)	0.00 (0.00)	0.00 (0.00)
Total-sky SW	99.3	-0.04 (1.35)	0.54 (3.10)	0.94 (1.31)	-0.94 (1.31)
Clear-sky LW	284.7	-0.29 (0.69)	0.30 (0.92)	0.01 (0.27)	-0.02 (0.26)

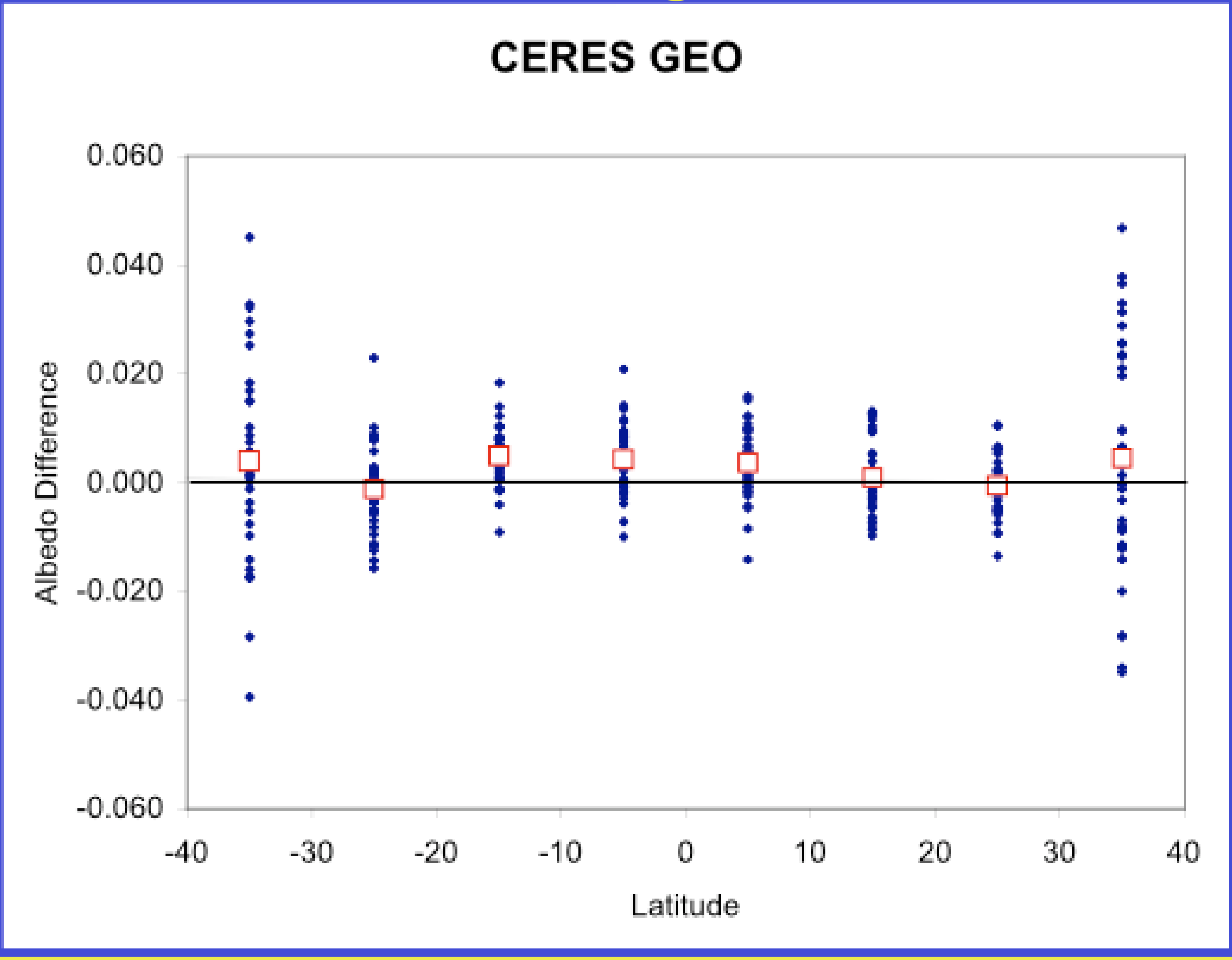
Direct Integration Approach

- Comparison performed on 10° x 10° grid
- May/June/July SRBAVG vs 2 TRMM precession cycles
- Direct Integration
  - Use CERES SSF footprint data from 2 46-day pression cycles
  - Save mean albedo vs sza (5° bins)
  - Integrate using correct solar weighting
- SRBAVG data
  - Combine 1° grid data on 10° grid from 3 months

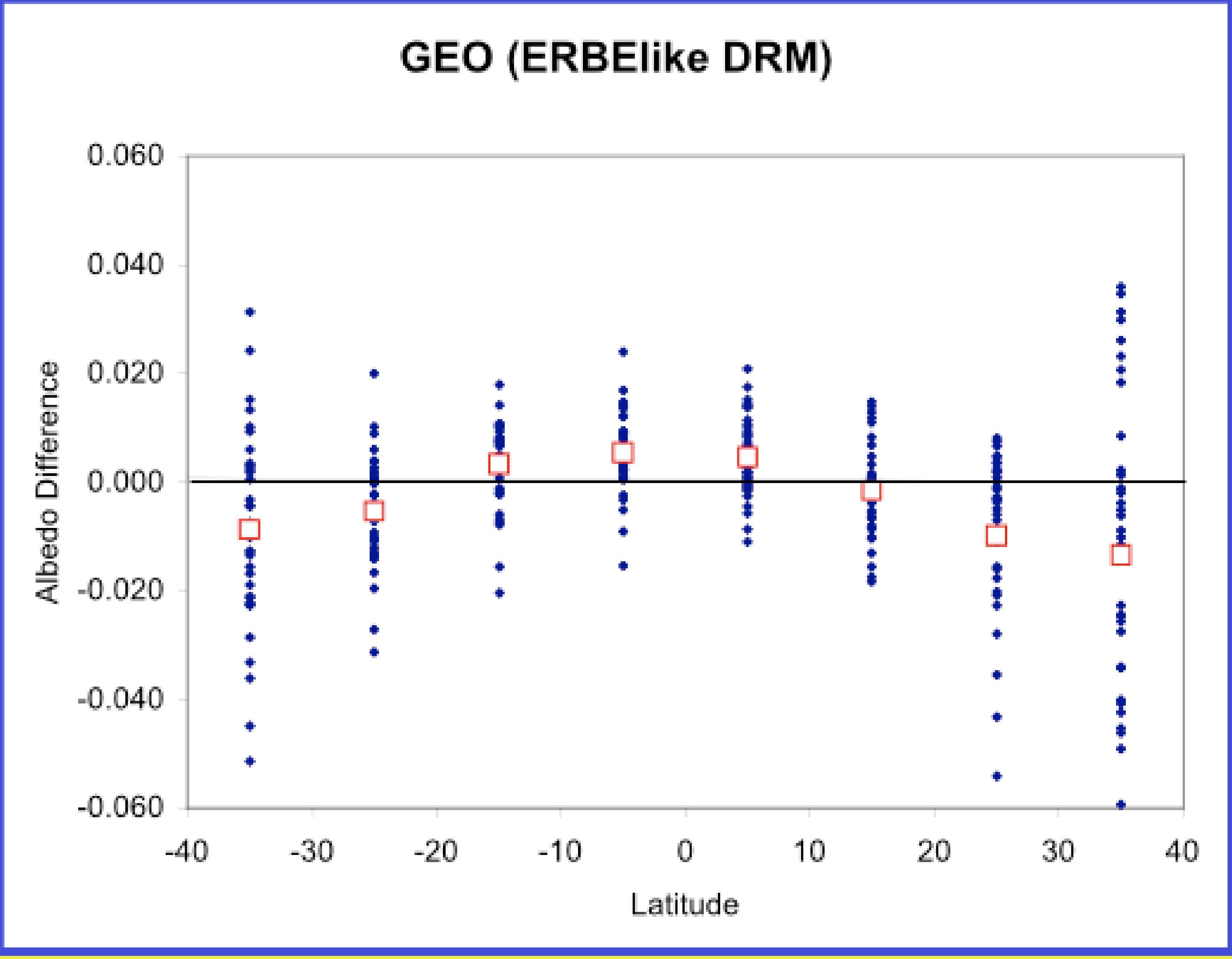
GEO - Direct Integration Albedo



GEO - Direct Integrated Albedo



GEO - Direct Integration Albedo (ERBE DRM)



Summary of Direct Integration Results

40N - 40S	nonGEO (CERES DRM)	GEO (CERES DRM)	GEO (ERBE DRM)
Mean Albedo Difference	0.001 (0.6%)	0.002 (0.7%)	-0.004 (-1.6%)
RMS Difference	0.010 (4.1%)	0.011 (4.3%)	0.017 (6.6%)

30N - 30S	nonGEO (CERES DRM)	GEO (CERES DRM)	GEO (ERBE DRM)
Mean Albedo Difference	0.001 (0.6%)	0.002 (0.6%)	-0.001 (-0.4%)
RMS Difference	0.006 (2.6%)	0.006 (2.7%)	0.011 (4.8%)

CERES Surface-Only Fluxes

•Downwelling clear-sky and all-sky SW and LW surface fluxes derived from relationships with TOA fluxes and atmospheric data.

•Each component computed from two models

		Model A	Model B
SW	Clear	Li et al.	LPSA
	All-sky	-	LPSA
LW	Clear	Inamdar and Ramanathan	LPLA
	All-sky	-	LPLA

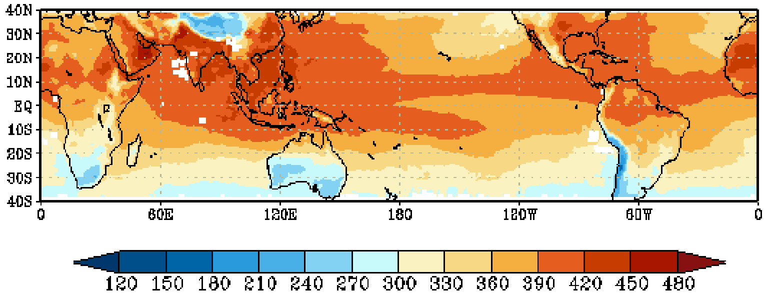
•Validation data sources:

ARM Central facility and extended facilities

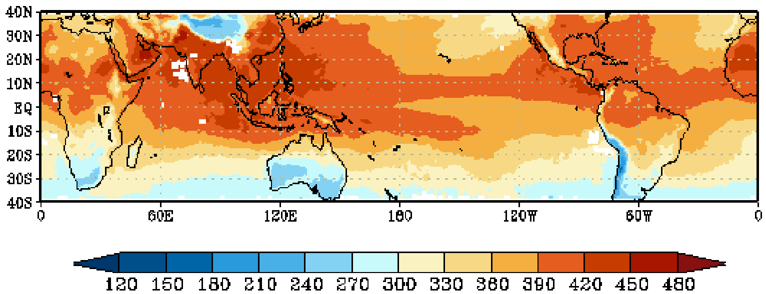
BSRN and CMDL sites

July 1998 Monthly Mean Surface Downwelling Clear-sky Flux

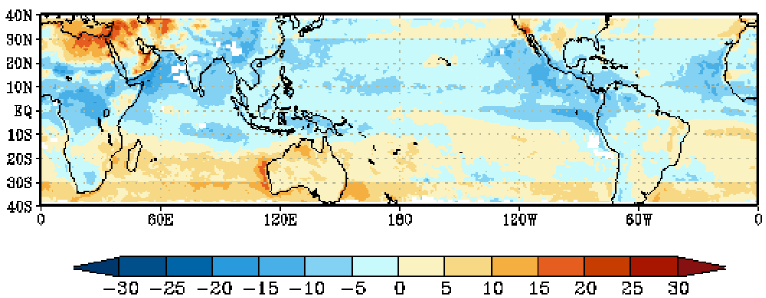
LW Model A



LW Model B

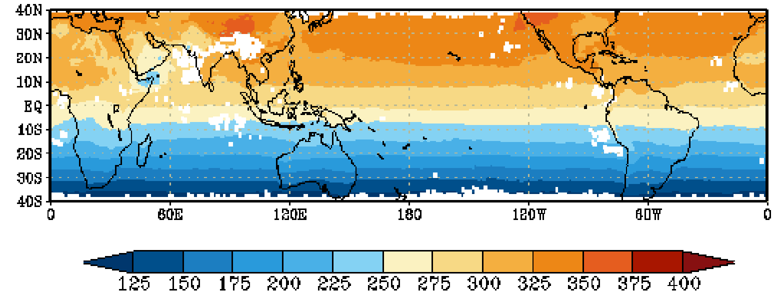


LW Model A - Model B

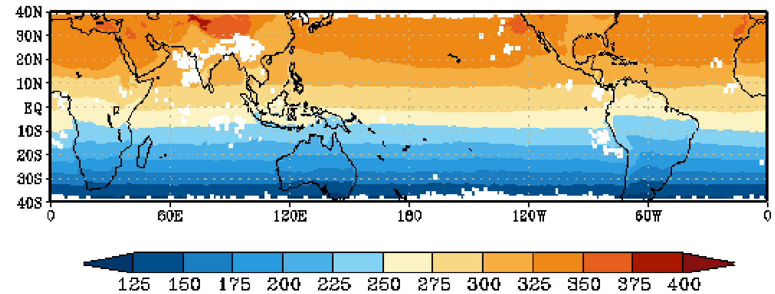


Mean -0.5 (-0.1%) Sigma 5.8 (1.6%)

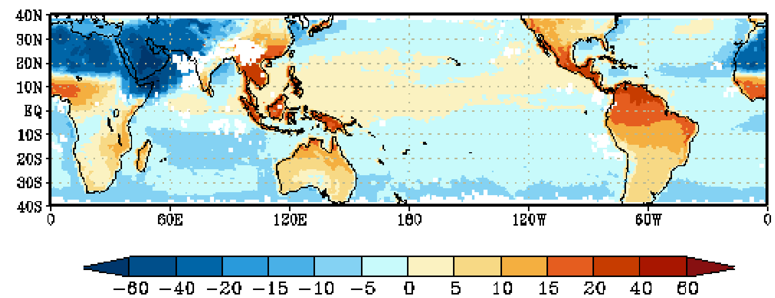
SW Model A



SW Model B



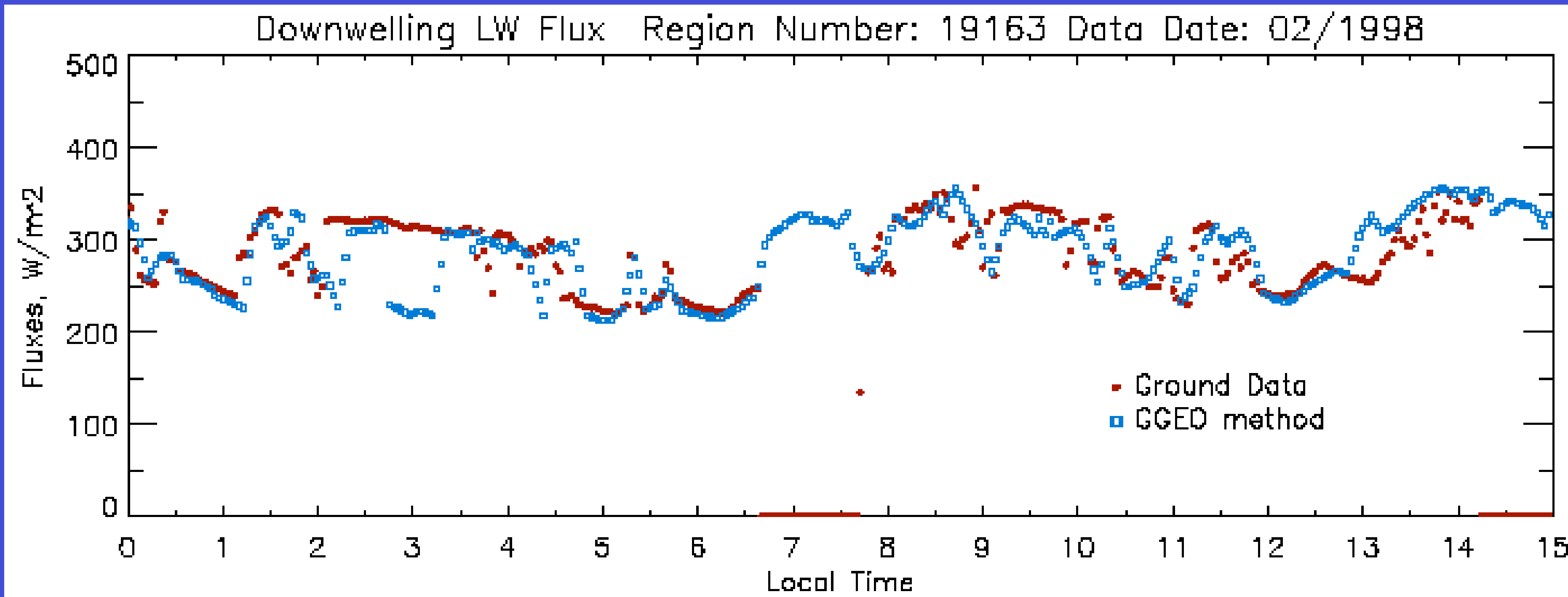
SW Model A - Model B



Mean -2.5 (-1.0%) Sigma 11.8 (4.5%)

Comparison with Surface-Based Measurements

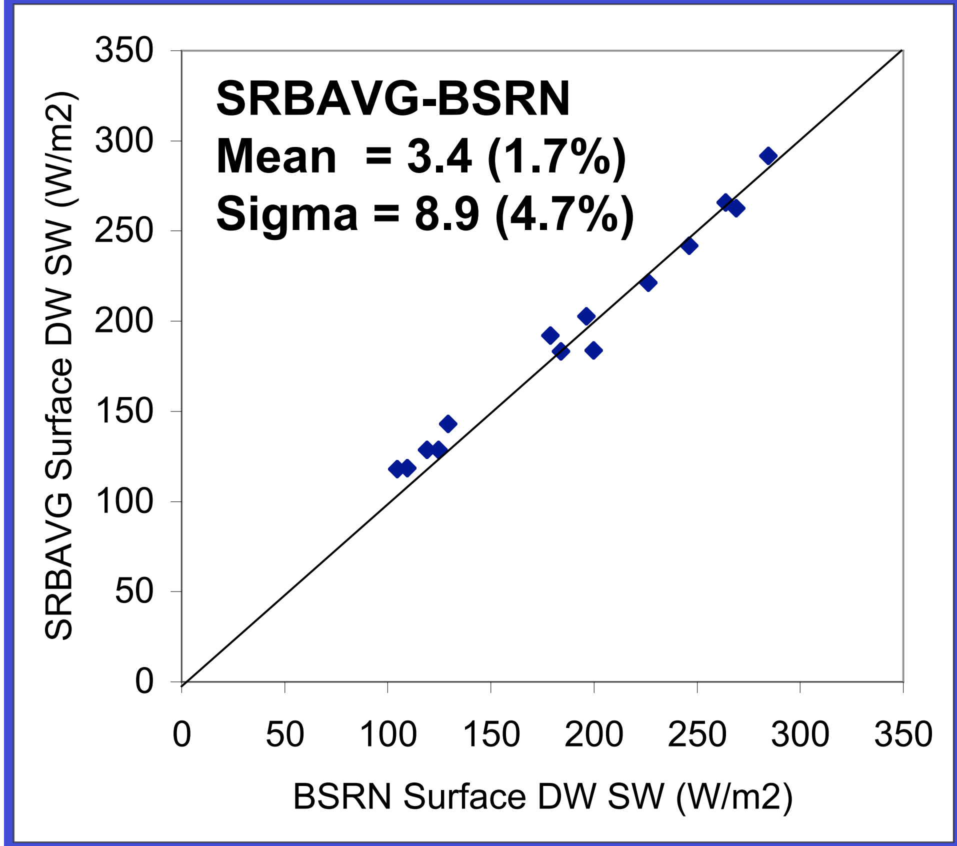
ARM SGP CF February 1998



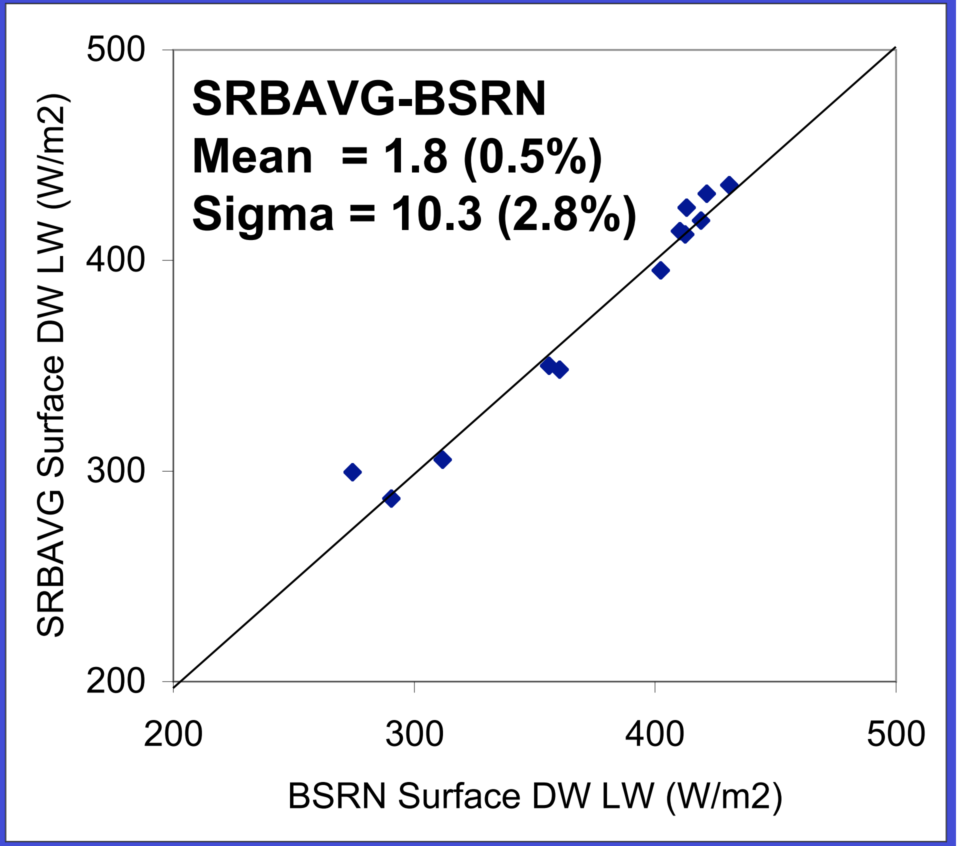
(W/m²)	Flux Bias	Flux RMS
Instantaneous	-0.05	19
Interpolated	-2.9	25

Monthly mean Total-sky Surface Flux SRBAVG vs. BSRN

SW Downwelling



LW Downwelling



TISA Validation Summary

- ERBElike, GEO and nonGEO monthly means typically agree on average < 1%
  - Difference consistent with sampling
- Direct integration results demonstrate no bias in SW modeling
- Calibration sensitivity
  - < 1% for 5% SW imager errors
  - ~0% for IR imager errors
- Surface flux comparisons
  - Errors similar to instantaneous comparisons
  - Monthly mean agree well with surface data
  - Additional months to be added soon

Status & Future Work

- TRMM SRBAVG available this month
- Terra Beta SRBAVG available soon
- TRMM Beta SYN by Spring
- Algorithmic improvements
  - Improved GEO cal
  - Improved NB/BB
  - Add daily means
- Validation
  - Full comparison with surface/SRB
  - GERB comparisons

End